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EASY INTRODUCTION

T O

MECHANICS,	MEASURING HEIGHTS
GEOMETRY,	AND DISTANCES,
PLANE	OPTICS,
TRIGONOMETRY,	ASTRONOMY.

To which is prefixed,

A N E S S A Y

O N T H E

Advancement of LEARNING by various Modes of
RECREATION.

By Mr. JOHN RYLAND, of NORTHAMPTON.

Illustrated with TWELVE Copper-Plates.

For the Use of Schools, as well as private Gentlemen.

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T H E

P R E F A C E.

THIS short treatise was drawn up, at my house, by a judicious friend, who is well acquainted with these sciences, and has a happy talent for communicating knowledge in the most clear and easy manner. I am not at liberty to mention his name, which would do me honour—excite the attention of the public—and very much promote the sale of the book.

I had long wanted an easy and familiar treatise of this sort, for the use of my scholars, and it gave me a most sensible pleasure, when I had prevailed on my friend to execute it.

The book with all the drawings, was begun and finished in less than six weeks. It is not designed for the learned; it was written for the use of boys, and, with no design to go any farther than my own school;

but the trouble of transcribing, with exactness, by each youth that wanted it, would be so great, as to prevent the easy communication of this kind of knowledge.

I am convinced, by more than nineteen years experience in the province of instructing youth, that much more may be done, than has been done, towards furnishing and adorning the human mind, in the early part of life. It is a grievous thing to consider, how we are suffered to waste seven or ten years, in learning little more than meer words, whilst the improvement of the understanding and the reason, is almost entirely neglected in most schools, through this kingdom.

The minds of youth are happily vacant of the cares and business of life; they are very receptive of ideas of all kinds, provided you propose them in a simple and familiar manner, and avoid every thing that is abstracted and remote from sense.

Logic, and metaphysics, though extremely useful to persons of riper understanding, are, by no means proper for young minds; almost every other branch of science, in the whole circle of learning, may
be

be proposed and communicated to ingenious youth, from ten to sixteen years of age.

The natural history of the air, the waters, minerals, plants, and animals, which is what we call sensible knowledge, may be infused with ease and pleasure into the infant mind, and certainly we have some of the best books for this purpose that can be well imagined.—I mean Mr. Pluche's beautiful work intitled *Spectacle de la Nature*, in 7 vol. 12mo. Dr. Brookes's *System of Natural History*, in 6 volumes, 12mo, with the beautiful sketches of every part of the creation in Mr. Hervey's works; as we never had a more passionate admirer of the beauties of nature, so no man perhaps in our nation had a richer imagination, or a better talent of strong and delicate expression than himself.

Arithmetic, and, geometry, are exceedingly useful and important sciences for youth, and they may be taught in a more pleasing and insinuating manner than they usually are. Every thing should be mixed with pleasure, and familiarity, that belongs to youth.

Arithmetic can never be enough taught; it deserves more attention than is given to it; we have two authors, who have made the science more easy and pleasant than ever—the one is the Rev. Mr. Stephen Addington of Market Harborough, in Leicestershire, the other is Mr. Daniel Fenning of London, their books in my opinion are the best adapted for the instruction of youth.—I beg leave to insert here a general canon for the rule of proportion, which I constantly use in my own school, and I would recommend it to masters of the younger class to insist upon it, that their scholars work every question in single proportion, in four different statings, this will strengthen the mind, and is the first and best method of teaching them the use of their reasoning powers that I am acquainted with.

GENERAL CANON OR RULE FOR SINGLE PROPORTION TRANS- POSED FOUR WAYS.

If four numbers or quantities are proportional, their order may be so transposed that each of those numbers or quantities may be last in proportion. And so of any four proportional numbers or quantities of
liquids

liquids or solids, if three be given the other that is wanting may be found thus.

AS FIRST SECOND THIRD FOURTH
1 : 4 :: 8 : 32

AS SECOND FIRST FOURTH THIRD
4 : 1 :: 31 : 8

AS THIRD FOURTH FIRST SECOND
8 : 32 :: 1 : 4

AS FOURTH THIRD SECOND FIRST
32 : 8 :: 4 : 1

Geometry, or the doctrine of extended or continuous quantity, including the consideration of lines, superficies and solids.—Next to divinity and history, this is certainly the very best science in which youth can be instructed.

It has a prodigious tendency to fix the attention, to strengthen and enlarge the mind, to improve the memory, to teach clear ideas, and an habit of just reasoning. It is surely the best logic that ever was invented for the use of mankind.

The first six books of Euclid's Elements may be taught to school boys, in a way of play, by working all the problems, and most of the theorems, in the sand. Let a young master of a school provide himself with a large pair of compasses, and a long ruler. Let him first take Le Clerc's Practical Geometry printed for Messrs. John and Carington Bowles, work one or two propositions, in the court yard, or playing place of his school every day, and in about six weeks, or two months, his scholars will be able to enter upon Euclid's Elements in the same manner. In a year's time, he may have twenty or thirty boys able to give a good account of the first principles of geometry, and plain trigonometry, without loss of time, or interrupting the business of their school hours.

I should reckon it a great honour to my school, to have it justly said, "that the boys are taught geometry, as a recreation, and, that Euclid's Elements were as familiar as the Latin accidence, or the numeration table. I am very sure, that all the parts of philosophy may be taught in the most easy and familiar manner, if school masters had but public spirit, good humour and condescension. In a word, if they had but a
fatherly

fatherly heart, and as much concern for the pleasure and improvement of their scholars, as they have for their own private gratification, and the inferior amusements of life. For instance—a fire shovel, tongs, and poker, will shew the foundation of the mechanic powers; especially the nature of levers.—A spinning wheel, will clearly shew the power of the wheel and axle—A brick bat on a table, will shew the advantage of broad above narrow wheels.—marbles, will teach a school boy the nature of percussion, and the laws of motion.—By the whipping and spinning of tops, we may shew the diurnal and annual motion of the earth.—The twirling of a chamber maids mop, will shew the nature of the centrifugal force of the planets.—The fall of a farthing ball, teaches the doctrine of gravitation, and the laws of falling bodies.—A pennyworth of quick silver, divided on a table, and some bits of cork in a bason of water, will shew you the attraction of cohesion.—A sponge will teach the rise of water in capillary tubes.—A syringe, or a squib, or sucking with a reed, or a wheaten straw, will shew the nature of pump work.—A school boy's jews harp, will serve to teach us, those tremulous motions, which are the cause of

a 5

sounds;

found; and a glass prism, and soap bubbles *, a looking glass, and an ox's eye, from the butchers will be a happy foundation for optics.—A few hoops, from the cooper's shop, placed with skill, will shew the grand circles of the sphere, viz. the horizon, the meridian, and equinoctial line, the ecliptic or sun's path, the two tropics, and the polar circles.

A small pillar, of the same size which is used for a barber's block, with a few rings of leather, or of horn, with some wires and wooden balls, will make a tolerable good orrery, to shew the situation, the distances, the motions, and magnitudes of the heavenly bodies, in the Newtonian system of astronomy.—Thus, I have given a few brief hints, how younger masters may pursue the most popular methods, with little expence, for the instruction, pleasure, and vast profit of their pupils, which would issue in their own honour and temporal advantage, and be an unspeakable satisfaction to the parents who entrust them with their dearest earthly treasure.

* Note, Let the man that laughs at this; be told that Sir Isaac Newton made a fine improvement in optics by seeing some boys blow up soap bubbles in the air.

I will, (now I am on the head of teaching the sciences, by way of recreation) advance this assertion, that all the branches of knowledge may be taught by cards.

The method of teaching the sciences, by the use of cards, is such as, perhaps in no other way can be so easy, so popular, so pleasant, and successful.

By cards I do not mean the common playing ones for gaming, which were first invented for the use of a lunatic French king, and continued in vogue to this day by millions of mankind, infected with a worse species of lunacy; nothing but the height of raging madness could ever spread such a foolish diversion so wide, or continue it so long, to the destruction of the peace of the mind, the pleasures of friendship, the health of the body, and the horrible ruin of thousands of fine estates and families.—But to such a height of insanity are multitudes arrived, as to render all means for their cure ineffectual; I therefore dismiss them in despair, with this one reflection; that, were I capable of wishing the greatest misery, to the worst enemy upon earth, and that he might be one of the most useless and contemptible animals in
the

the world, I would wish him to be a constant and infatuated card-player.

But whilst common sense, and the love of one's country can despise and abhor so foolish and insipid a diversion, this same common sense, and public spirit can invent a thousand ways by which cards, that is to say, the same kind of blank papers, which are used for cards, may with very different kind of furniture and application, be promotive of the glorious purposes of science and virtue, some of these pleasant uses we will now explain.

FIRST, GEOGRAPHICAL CARDS.

Take a pack of blank or message cards, write on them the principal cities of Europe, Asia, Africa, and America, one city on each card, with the latitude, longitude, number of inhabitants, and their religion. When you have compleated the furniture of these cards, the manner of playing with them is as follows. In a rainy day, or a winter evening, when the weather does not permit them to play in the open air, let two, three or four boys, agree to play at a
game

game of geography ; deal out the cards and let the first boy begin, draw a card, inspect it, name only the city, and turn it's face downward on the table. The second boy must answer, thus for example. Suppose it was London. London (replies the second) is the capital city of the kingdom of England, it's north latitude is 51 degrees, and 32 minutes, it's longitude is nothing, because the first degree of longitude, or the first meridian, begins at London. The number of inhabitants in the city and suburbs, are reckoned near a million, or ten hundred thousand ; and the people profess the protestant religion.

If the second boy, gives a true account of what is upon the first card, he has a right to play one of his, and the third boy must answer. But if the second boy misses, and the third boy answers truly, then he sits above him, or takes his place, plays his card, and the second boy is obliged to answer, if he mistakes again, and the fourth boy names right, he takes his place, and the second boy is put lower with disgrace. And thus let the boys go on, till their cards are all played out ; and let him that has made the fewest blunders, be called the captain for that day.

II. CARDS

II. CARDS OF ANTIENT HISTORY, WITH THE CHRONOLOGY ANNEXED.

The furniture of a pack of blank cards with antient history must be thus ordered. On the first card write on it thus :

FIRST EPOCH.

ADAM, OR THE CREATION,
FIRST AGE OF THE WORLD.

ANNO MUNDI,	ANTE CHRISTUM.
YEAR OF THE WORLD,	BEFORE CHRIST,
O	4004

On the second card write, *Second* epoch, Noah, or the deluge, with the year of the world, and the years before Christ. — *Third* epoch, the call of Abraham. — *Fourth* epoch, Moses, or the written law. — *Fifth* epoch, the destruction of Troy. — *Sixth* epoch, Solomon, or the temple finished. — *Seventh* epoch, Romulus, or Rome founded. — *Eighth* epoch, Cyrus, or the Jews restored. — *Ninth* epoch, Scipio, or the conquest of Carthage. — *Tenth* epoch, the birth of
Jesus

Jesus Christ; which is the seventh age of the world

ANNO MUNDI	ANNO ROMÆ	ANNO CHRISTI
4004	754	I

Let every young person, according to his ability, after he has placed the above furniture on one side of his cards, write some peculiar select facts which happened in each period, on the other side. By this means he will have many of the most beautiful and delicate parts of antient history at an easy rate within his power; and school-boys may play at cards of this sort with as much pleasure and profit, as, with the geographical ones first mentioned.

III. CARDS OF MODERN HISTORY, WITH THE CHRONOLOGY ANNEXED.

The best way of treating modern history, is to divide it into centuries, beginning with the birth of Jesus Christ, and to denominate every century according to the principal facts transacted in that century. And I can think of nothing better than the epithets of that learned historian, Dr. William Cave, viz.

He

He files

Century I.	Sæculum Apostolicum.
Century II.	Sæculum Gnosticum.
Century III.	Sæculum Novatianum.
Century IV.	Sæculum Arianum
Century V.	Sæculum Nestorianum.
Century VI.	Sæculum Eutychicum.
Century VII.	Sæculum Monotheliticum.
Century VIII.	Sæculum Eiconiclasticum.
Century IX.	Sæculum Photianum.
Century X.	Sæculum Obscurum.
Century XI.	Sæculum Hildebrandinum.
Century XII.	Sæculum Waldense.
Century XIII.	Sæculum Scholasticum.
Century XIV.	Sæculum Wicklevianum.
Century XV.	Sæculum Synodale.
Century XVI.	Sæculum Reformatum.
Century XVII.	Sæculum Doctissimum.
I add to Dr. Cave,	
Century XVIII.	Sæculum Luxuriosum.

IV. GEOMETRICAL CARDS.

The first and easy principles of geometry may be placed on cards in the following simple manner, and a figure should attend each definition to make it more easily understood. On the first card fix a point.—
On

On the second, a secant point. — On the third, a central point. — a right line — a circular line — curve line — a mixed line — a plumb line — a perpendicular line — horizontal line — oblique line — parallel lines — a base line — finite lines — infinite lines — apparent line — occult line — diagonal line — diameter line — spiral line — chord line — an arc — a tangent line — a secant line — a right lined angle — a curve lined angle — a mixed angle — a right angle — an acute angle — an obtuse angle — and from thence proceed to all sorts of surfaces. This will lay a sure foundation for plain geometry, and prepare the ingenious boy for reading Euclid's Elements with pleasure and success.

V. OPTICAL CARDS.

Optics, or the consideration of the nature of light, and the human eye, is one of the most sublime sciences in the world. Its first principles may be infused into school-boys in the following easy manner : take some blank cards, let any ingenious man draw the figures, and write underneath, the easiest definitions, from Dr. Rutherford's System of Philosophy, viz. —
a ray

a ray of light — the inflexion of a ray of light — the refraction of a ray of light — the reflexion of a ray of light — the angle of incidence — the refracted angle — the angle of refraction — the angle of reflection — diverging rays of light — converging rays of light — parallel rays of light — a radiant point — a focus — a focus changed into a radiant — a double convex lens — a plano — convex lens — a double concave lens — a plano-concave lens — a meniscus, or concavo-convex lens — a plane glass — a flat convex glass — a prism — the axis of lens glasses — the poles or vertexes of a lens — diverging rays falling on a lens form a cone, whose apex is the radiant point, and the lens is its base — the axis of a beam of light — direct rays upon a lens — oblique rays upon a lens — a pencil of rays — the human eye — the outer coat of the eye, called the Sclerotica — the middle or black coat of the eye, called the Choroides — the inner coat of the eye, or net work, called the Retina — the three humours of the eye, viz. the Aqueous, or watry humour of the eye — the ChrySTALLINE, or brightest humour of the eye, in the form of a double convex lens — the Vitreous, or glassy humour of the eye. N. B. When these first principles and definitions are clearly understood and well remembered, it will be easy and pleasant to
 proceed

proceed even to Sir Isaac Newton's most beautiful and incomparable Treatise on Optics, which is much more within the power of good common sense than is usually imagined.

VI. CARDS OF ANATOMY.

The structure and beauty of the human body ought to be studied with delight and admiration by every man; and the knowledge of this elegant fabric may be conveyed into the minds of youth, with great ease and pleasure, by the use of cards. I shall only exemplify it a little with regard to the bones, and refer my ingenious young friends to that most exquisitely delicate and alluring description of a human body, which he will find in Mr. Hervey's Theron and Aspasio, Dialog. XII.

Let an ingenious young man take Cheselden's Anatomy, or the Tables of Anatomy engraved by Mr. Tinney, in Fleet-street, on folio sheets; with his pencil copy on a blank card one bone, with its name; and thus proceed with his cards through the principal bones of the human body. And lest I should not be thoroughly understood,
or

or the minds of young persons be too indolent to pursue my advice, I will lead him farther, and mention the names of the bones, which are these : Os frontis — os bregmatis — os temporis — os occipitis — os jugale — clavicula, or collar bone — sternum, or breast bone — seven vertebræ of the neck — twelve vertebræ, or joints of the back bone — five vertebræ of the loins, in all twenty-four joints—seven true ribs of a side five false ribs — the scapula, or shoulder-blade — os humeri, or bone of the arm above the elbow — the radius and ulna, the two bones of the arm below the elbow — bones of the carpus or wrist — bones of the metacarpus or hand — bones of the fingers — the os sacrum — os coccygis — os ilium — os pubis — os femoris, or bone of the thigh — the patella, or knee-pan — the tibia, or largest bone of the leg — the fibula, or least bone of the leg — os calcis, or bone of the heel — the tarsus, or six instep bones — the metatarsus, or bones of the foot — lastly, the bones of the toes. These, with the smaller bones, may be numbered thus: about sixty in the head and neck; sixty in the arms and hands; sixty in the trunk of the body; and, sixty in the thighs, legs, and feet; in all, about two hundred and forty. And with these
the

the all-wise and powerful God has built the structure of the human body; and for which he deserves eternal love and adoration. I do not advise young men to study this science with the accuracy of anatomists, but as a profitable and rational recreation, in order to increase their veneration for our omnipotent and good creator; and, I can assure them, after more than twenty years experience, that the pleasure and profit of this study will richly reward them for their labour.

VII. CARDS OF ASTRONOMY, AND
A LIVING ORRERY, MADE WITH
* SIXTEEN SCHOOL-BOYS.

Astronomy is a most sublime and delicious science: To form a just idea of the magnitude, motions, and distances of the heavenly bodies, has a powerful and happy tendency to enlarge and elevate the soul, and to give us striking thoughts of the wisdom, goodness, and universal agency of God. But can any notion of this science be conveyed into the minds of school-boys? Will it not rather puzzle and confound their brains, and unfit them for the more important employment of studying dry
words

words for seven years together ? I answer, No. It may be taught them in their play hours with as much pleasure as they learn to play at marbles, or drive a hoop for an hour or two ; and this may be done in manner and form following :

Take sixteen blank cards ; write on one, the sun, a seventeenth boy of a large size must be used for the sun in the center, with his diameter, which is seven hundred thousand miles. On another card write mercury, with his period, eighty-eight days, distance from the sun thirty-two million, diameter two thousand six hundred miles, and hourly motion, which is one hundred thousand miles. So go on to venus, our earth, mars, jupiter, and saturn. Then write on your other cards the names and periods of the ten moons in our system. Having thus furnished your cards, then provide the orbits for these sham planets, go into any plain field, or place, where boys can play, draw a circle of two hundred feet diameter, which you may easily do with a cord and a broomstick, ordering one boy to hold the cord in the center, while you describe the circle with the stick at the other end of the string. When you have formed your circle, divide the semi-diameter into a hundred parts ; if you chuse exactness,

ness, take five of these parts from the center and describe a circle for mercury's orbit, take seven parts for the orbit of venus; ten parts for our earth's orbit; fifteen parts for the orbit of mars; fifty-two parts, that is fifty-two feet for the orbit of jupiter. And let the outward circle of a hundred feet represent the orbit of saturn, which is the boundary of the Newtonian system. After this draw your circles for our moon round the earth, for jupiter's moons round him, and last of all for saturn's five moons. There is no occasion to be scrupulously exact till the boys are well versed in these first easy notions, reduce them to accuracy by degrees. Mr. Whiston's Astronomical Principles of Religion, and Mr. Ferguson's Astronomy will furnish you with ample materials for all your purposes. Now begin your play, fix your boys in their circles, each with his card in his hand, and then put your orrery in motion, giving each boy a direction to move from west to east, mercury to move swiftest, and the others in proportion to their distances, and each boy repeating in his turn the contents of his card, concerning his distance, magnitude, period, and hourly-motion. Half an hour spent in this play once a week will in the compass of a year fix such clear and sure ideas of the solar system

system as they can never forget to the last hour of life. And probably rouse some sparks of genius, which will kindle into a bright and beautiful flame in the manly part of life.

AN ADDRESS TO THE INGENUOUS YOUTH OF GREAT BRITAIN.

Young Gentlemen,

The design of this address to you is to give you a few brief hints concerning some select books on the principal branches of science in order to shorten your path to good learning and strew it with flowers. I know by the painful experience of above thirty years what it is to pant for knowledge and books, sometimes without any guide, sometimes with insufficient and ignorant ones, sometimes with men of learning without genius, sometimes with men of genius and furniture, but too lazy and indifferent, or swelled with pride and a haughty stiffness, or possess of no talent for the communication of knowledge, or

no inclination or condescension to accommodate themselves to the capacity and taste of enquirers after truth.

But the greatest defect I have ever found in learned men is a want of public spirit, and a fervent love to the rising generation: this is the worst part of their temper, and an indelible stain in their character; for which they deserve the severest rebuke.

We have in this nation men well versed in all the sciences, and all the branches of learning were never better understood than at present. But if every learned man had a true love to the rising generation and a condescending temper, I will venture to aver that in seven years time, where we have one man of real knowledge *now*, we might have an hundred, or perhaps five hundred *then*. We should not see such ignorance in thousands of our ministers of religion: nor such wretched and shameful unacquaintance with the history, laws, and government of their country, as hath fully appeared in multitudes of our young nobility, and I am sorry and grieved to say it, in the majority of the representatives of a brave and powerful people.

Now my dear ingenious youths, let me offer you a little assistance, give me your hand, and let me lead you into a most beautiful and pleasant path, which I myself have trod. I do not pretend to write for men, nor for those young persons who have skilful tutors always to attend them. I write for all those who have a good natural taste, and a passionate fondness for real knowledge, but want an experienced guide, to such the following hints will not be unwelcome, nor unserviceable.

Do you in the first place wish for two or three excellent books to guard you from errors in study, and to be your faithful guides in the pursuit of solid learning : then my dear boys read above all authors Dr. Watt's Improvement of the Mind, 8vo. Mr. Locke's Conduct of the Understanding, 12mo. and John Clarke's Essay on Study, 12mo.

Would you gain clear and beautiful ideas of the works of creation, read Pluche's Nature Displayed, 4 vols. 12mo. Dr. Brooks's Natural History, 6 vols. 12mo. Ray on the Wisdom of God in Creation, 12mo. Wesley's Compendium of Natural Philosophy, 2 vols. 12mo. Dr.
Cotton

Cotton Mather's Christian Philosopher, 8vo. 1721. Dr. Derham's Physico Theology, 2 vols. 8vo. Cambray on the Existence of God, 12mo. a new beautiful edition of which is just publishing. Martin on the Existence of a Deity, from Sixteen Fountains of Evidence, and his Young Gentleman's and Lady's Philosophy, 2 vols. 8vo.

These are the best books, and the easiest to introduce you to Voltaire's Elements of Sir Isaac Newton's Philosophy, translated from the French, 8vo. 1738. an excellent book. Algarotti's Six Dialogues on Sir Isaac Newton's Philosophy, 2 vols. 12mo. 1739. Rowning's Compendious System of Natural Philosophy, 2 vols. 8vo. Martins xii Lectures on all the Branches of Experimental Philosophy, intitled Philosophia Britannica, 2 vols. 8vo. and to crown all, Dr. Rutherford's System of Natural Philosophy, 2 vols. 4to. 1748. If your inclination should lead you to enquire farther after books on natural philosophy, you may be directed to the utmost of your wishes, in Johnson's Quæstiones Philosophicæ, 12mo. Cambridge, 1735.

If ever your genius should grow strong enough to taste the pleasures of science, abstracted from sense, and the rational entertainments arising from the consideration of the doctrine of being and of spirits, I advise you to read but a few select books, the best I am acquainted with are Dr. Watts's Scheme of Ontology, at the end of his philosophical essays, and Dr. Doddridge's Pneumatology in his Lectures, 4to. 1762.—I have in MS. Mr. Henry Grove's beautiful System of Pneumatology. I wish from my heart that some bookseller would venture to print it, on the footing of a subscription from the learned world. This ingenious writer certainly was one of the clearest thinkers on metaphysical subjects that our age has produced.

Have you a taste for the knowledge of numbers and quantity? Read and study these books, Mr. Addington's System of Arithmetic, 8vo. Le Clerc's Geometry, 12mo. Dechale's Euclid, 12mo. Whiston's Edition of Euclid, 8vo. 1714. These two editors of Euclid, shew the practical uses of the problems and theorems; and will remarkably strengthen your habit of attention, teach you to sift and compare your ideas, and
enlarge

enlarge your reasoning powers in a remarkable manner.

Do you desire to form a familiar acquaintance with the first principles of natural religion, and moral philosophy? Read Sir Richard Blackmore's *Natural Theology*, 8vo. 1728. Wollaston's *Religion of Nature Delineated*, 4to. Reimarus on *Natural Religion*, 8vo. Fordyce's *Elements of Moral Philosophy*, 12mo. 17. and to compleat your studies on this head, read Grove's *System of Moral Philosophy*, 2 vols. 8vo. I freely own I prefer this for the favour of piety and delicate composition, beyond Dr. Hutchenfon's *System*, 2 vols. 4to.

Do you love the grand science of society, government, and the laws of your country? This is indeed a most noble and important object of the human understanding: it gives an amplitude to the soul, and leads to a most exalted idea of the divine government of the universe. I am so far from advising you not to study politics, that on the other hand, I counsel you to employ your powers very often on the glorious structure and excellence of the British constitution; and to assist you in

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your

your views, read the best books that were ever written, since Britain existed, Milton, Sydney, Locke and Dr. Campbell, Sydney's Treatise on Government, folio, 1696. Locke on Government, 8vo. Dr. Campbell's Present State of Europe, 8vo. 5th edition, and his excellent Sketch of Laws and Government published in the Preceptor, vol. 2. to these books add Dr. Blackstone's Commentaries on the Laws of England, 2 vols. 4to.—These are certainly superior to every work of the kind, that have appeared in our language.

Above all things my dear young friends, study the evidences and contents of the CHRISTIAN RELIGION. The greatest and best step you can take for this purpose, is to consider deeply and accurately, the insufficiency of human reason to lead you to eternal happiness, in the full fruition of the supreme good; study this subject to the utmost of your capacity, I can assure you after twenty-two years incessant labour and thought on this most important and momentous point, that nothing does more mortify our native pride, and conceit of our strength of reason than a just and impartial view of its insufficiency, to conduct us to the highest end of man. If you do
not

not believe me, try what you can do without your bible; summon up your best powers, and exert the utmost force of your genius to attain a clear and extensive knowledge, of the attributes and providence of God; find out the true way of worshipping God; tell me in the most convincing manner, wherein consists the solid happiness of human nature; declare to me and the world, the chief good of the soul; draw out a system of true morality without any defect; explain every duty we owe to God and mankind; produce the richest, and most persuasive motives to excite to the exercise of every virtue; display such powerful reasons, as shall prevail with every man, to discharge the whole of moral obligation, and persevere in virtue and goodness to the last moment of his life; give me a most satisfying account of the origin of moral evil, which has ever raged with such dreadful power and malignity all over the rational world; and shew me how this may be pardoned so as to satisfy a serious enquirer, and calm a guilty conscience; demonstrate to me by the strength of your reason, how one sinner, how millions of sinners, may be introduced into the favour and friendship of God, notwithstanding all their past offences,

and be happy in him for ever ; assure me of an effectual means to curb every licentious passion, every vile appetite, every vicious inclination, every impure imagination and taste ; shew me a sufficient fund of moral and proximate power, to raise me above the wicked spirit and polluted manners of the whole world, and to persist in virtue and goodness in spite of all temptations, to my last hour.

If you think the powers of reason are sufficient to conduct you to the supreme good and final happiness of man ; try your utmost strength to support yourself under the troubles of life, and the vexations and crosses, you meet with in mind body, and estate ; fortify yourself against all the terrors and stings of death ; act a courageous part, when that ghastly monarch, who is stiled by an ancient and very acute philosopher * *the terrible of all terribles*, shall come to separate your soul and body ; to turn the mortal part of your nature into corruption and dust, and fix your character and state in another world, which you must enter into with all your thinking powers, and most lively consciousness for evermore. Now if you have fortitude
enough,

* Aristotle.

enough, meet this king of terrors, and without the assistance of divine revelation, address him boldly. O! death, where is thy sting? O! grave, where is thy victory?

This method of proceeding in order to prepare you, for studying the evidences and contents of the christian religion, is the best that can be thought of; because it has a direct tendency to humble the pride of your nature, to abase the high conceit which every man forms of his own strength and goodness of heart; and such considerations as these, will bring you to the dust as a guilty ruined creature; utterly insufficient to conduct yourself to the final perfection of your faculties, and the ultimate happiness of your immortal spirit.

In this temper of mind set yourself to examine the evidences of the truth and divine authority of the christian religion. To assist you in this affair of infinite moment, I recommend to your perusal Dr. David Jennings's two discourses intituled, An Appeal to common Sense for the Truth of the Scriptures, and Dr. Doddridge's three sermons on the Evidences of Christianity, 12mo. price 8d. — These are perhaps the most
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clear

clear and convincing of any sermons in our language; but the most extensive view of the whole subject, in all its parts and connexions, that has appeared in our world, you will find in Dr. Doddridge's Course of Divinity, 4to. 1763. including LIII. lectures (viz.) from lect. CI. to lect. CLIV. It is an act of justice to acknowledge, that no one single book of a theological nature has equalled this in our land: and it is an honour to the good sense and candour of some gentlemen, in public seminaries, that they have paid a proper attention to this excellent course of lectures on pneumatology, ethics and divinity*.

In order to make your enquiries more easy, pleasant and successful, I will lead you on a little farther. Our most learned and judicious divines have a thousand times observed, that revelation stands on four principal pillars, or, in other words, is supported and confirmed by four capital arguments, viz. the fulfilment of prophecies — the working of miracles —

* This celebrated work was the result of thirty years accurate study and labour, with the revival of all his best friends and correspondents.

the goodness of the doctrine — and the moral character of the pen-men,— especially the divine character of the great founder of the christian religion.

I. FULFILMENT OF PROPHECIES.

This is a glorious argument to demonstrate the divine truth and authority of the holy scriptures; and it has this excellence, that its evidence is ever growing by the accomplishment of many prophecies now in the world. No age or country has been blessed with a brighter display of this evidence in its vast extent and connexion than our own. It is enough to name Dr. Newton's 3 vols. of Dissertations on Prophecy; it would be an affront to common sense to say any thing in favour of a work which is so generally known and esteemed, and which surpasses all commendation. However, it will be no disparagement to that incomparable work, to mention Dr. Gill's Treatise on the Prophecies fulfilled in the Messiah, 8vo. 1728. The judicious Mr. Robert Fleming's Treatise on the fulfilling of the Scripture, a small folio. And the excellent Mr. Benjamin Bennett's Discourses on the Fulfilment of Scripture, towards
good

good and bad Men, in his Sermons on Inspiration, 8vo. 1730. Let me advise you to study this argument thoroughly: make yourself master of the subject in all its parts.

Nothing strikes a wise man's mind so strongly as facts, and it must give you unutterable pleasure to observe how the bishop of Bristol confirms and illustrates the prophecies and facts of scripture, by a judicious and most happy application of passages selected from antient history. It is no dishonour to this great man to say, that our learned Dr. Prideaux, and an author who is the glory of the kingdom of France, and whose name and writings will ever be dear to me, paved the way for Dr. Newton and pointed out the method which he has so well pursued. Would you know this last author? He is the amiable, I had almost said the DIVINE, ROLLIN.

II. THE WORKING OF MIRACLES.

This is another excellent and most convincing argument to prove the divine inspiration of the holy scriptures; and taken in connexion with the fulfilment of prophecies on the one hand, and with the goodness

goodness of the doctrine on the other, it rises up almost to irresistible demonstration.

I will not mention a thousandth part of what has been said for or against this head of argument; but will shew you the plainest and most pleasing method of beginning your considerations upon it, so as to produce the most striking conviction of its glory and evidence, only remarking, by the way, that the Deists have of late, as well as in former days, employed their utmost art and force to overthrow this argument, particularly David Hume, and Rousseau. The former has been fully answered by the late Dr. Leland, in his *View of the Deistical Writers*, Vol. II. 8vo. and by the Rev. Mr. Richard Price, F. R. S. in his *Dissertations* just published. The latter i. e. Rousseau has been effectually confuted by one of his own country men and fellow citizens, Dr. Claparede, professor of divinity at Geneva, whose work has been translated from the French, and printed this year in London for Mr. Newbery, 8vo.—I would advise you to read this little treatise on miracles with attention, as it is written with remarkable clearness and precision and contains

contains the substance of what you will find in larger volumes.

But suppose you had no book on miracles except your bible, what would you do in order to have a clear and extensive view of this subject, and answer your great end, which is a full and compleat conviction that the sacred scriptures are inspired from heaven? I will satisfy you, my dear young friend; I will point out to you the most easy and effectual method of studying this subject.

The first thing I advise you to do is this, endeavour to attain the clearest idea of a MIRACLE.

The learned and judicious Mr. John Hurrion * defines a miracle thus — “Miracles are extraordinary works of God, above, beyond or contrary to the course

* His sixteen excellent sermons, p. 436, intitled, The scripture doctrine of the proper divinity real personality, and the external and extraordinary works of the Holy Spirit, stated and defended at Pinners-hall, 1729, 1730, 1731. 8vo. Oswald in the Poultry, 1734.—Note. Few people in the world know the worth of these sermons. On the subject they have no equal.

of

of nature, or the power of second causes, done to confirm the truth."

Dr. Doddridge * defines a miracle thus, "When such effects are produced as (*cæteris paribus*) are usually produced, God is said to operate according to the *common course of nature*: but when such effects are produced as are (*cæt. par.*) contrary to, or different from that *common course*, they are said to be MIRACULOUS."

Dr. Claparede's † definition is the shortest and most easy to be understood, "A miracle is a sensible change in the order of nature." Nature is the assemblage of created beings.

These beings act upon each other, or by each other, agreeable to certain laws; the result of which is what we call the order of nature.

These laws, being a consequence of the nature of these beings, and of the relations which they bear to each other, are

* See his lectures, part V. lect. CI. definition LXVII.

† Read his considerations upon the miracles of the gospel, 8vo. 2s. 6d. Newbery, 1767.

invariable;

invariable : it is by them God governs the world. He alone established them. He alone therefore can suspend them.

The proper effect then of miracles is to mark clearly the divine interposition, and the scriptures suppose that such too is their design. Hence I draw this consequence, that he who performs a miracle performs it in the name of God and on his behalf, that is to say, in proof of a divine mission.

But what are the characters of true miracles ? How may we know that the master of nature hath been pleased to modify or suspend its laws ? A question of the highest importance !

We have a clue to guide us in this research : since the end of miracles is to mark the divine interposition, the miracle must have characters proper to mark this interposition. 1st. It must have an end important and worthy of its author. 2. Be sensible and easy to be observed. 3. Be independent of second causes. 4. Be instantaneously performed.

Now, my young friend, proceed to take a survey of the miracles in what I would call

A

A COMPENDIOUS VIEW OF THE MIRACLES RECORDED IN THE BIBLE.

Deluge — confusion of languages — fire on Sodom — burning bush — rod turned into a serpent — rivers made blood — the plague of frogs — dust turned into lice — swarms of flies — murrain on the cattle — boils on man and beast — hail mingled with fire — locusts — darkness to be felt — death of the first born — red sea divided — bitter waters of Marah sweetened — rock gushes out with water — law given at Sinai with thunder, fire, and earthquake — quails given to eat for 600,000 men — manna given every morning for 40 years — Nadab and Abihu burnt with fire — earth opens to swallow up Korah, Dathan, and Abiram — brazen serpent curing — a dumb ass speaking with an human voice — Jordan divided — sun and moon standing still for a whole day — Gideon's fleece — powers of Sampson — water flowing from a jawbone — meal and oil multiplied — widow's son raised — no rain for three years — Shunamites son raised — the wonders of Elijah and Elisha — Naaman's leprosy cured

cured — Gehazi made a leper for life — one hundred fourscore and five thousand Assyrians killed in one night — the sun on the dial of Ahaz going ten degrees backward — three heroes in the fiery furnace — a man's hand writing on the wall — lions refusing to devour Daniel in the den — a fish swallowing Jonah, and after three days and three nights vomiting him up alive upon the dry land !

MIRACLES OF THE NEW TESTAMENT.

The man Jesus born without an earthly father — water turned into wine — a nobleman's son restored — leper cleansed — centurion's servant healed — burning fever in Peter's wife's mother removed — a raging tempest calmed — legion of devils driven out — palsy cured with a word — Jairus's dead daughter raised — issue of blood of twelve years standing effectually removed — dumb man made to speak — two blind men made to see — withered hand restored — a man, made blind and dumb by the devil, restored to sight and speech — five thousand fed with a few loaves and fishes — Jesus walk-
ing

ing on the watry world — a poor woman cured by touching the hem of his garment — Syrophœnician woman's daughter restored — a man by the devil made a lunatick cured — a fish bringing the tribute money in his mouth — fig tree withering away — deaf and stammerer restored to hearing and free speech — four thousand fed — wonderful draught of fishes — widow's dead son raised — seven devils cast out of Mary Magdalen — a woman crooked for eighteen years made straight — ten lepers cleansed — a man impotent for thirty-eight years healed — a man blind from his birth made to see — buyers and sellers whipt out of the temple, — (this is thought the greatest miracle) — Lazarus dead and putrified restored to life — darkness at Christ's death — Christ's own resurrection, a glorious miracle ! — the Saints arising with Jesus — a net full of great fishes, (one hundred and fifty three) yet the net not broken.

Note. 1. Explain the precise circumstances of each miracle. 2. Make pertinent and striking reflections on each.

III. GOOD-

III. GOODNESS OF THE DOCTRINE.

This is the most popular, convincing and attractive argument, to prove the divine inspiration of the scriptures.

Good, in its most simple idea, signifies any thing that is suited to please our taste or promote our happiness — natural good, is any thing that is fitted to answer its end — metaphysical good is whatever is agreeable to the intention of the great and wise creator — natural good, as considered with relation to sensible or rational and intelligent beings, signifies what is pleasant, or that which tends to procure pleasure or happiness.

Good, in a rational sense signifies any being or thing that is possess of such perfections as are proper for any valuable and important end.

The goodness of a thing is its fitness to produce any particular end that is valuable and important to a reasonable creature.

The goodness of the doctrine of revealed religion is its suitability to increase our pleasure,

pleasure, diminish our pain, continue the presence of good, and to remove the pressures of evil.

Goodness, in the sense in which we use it on this occasion, signifies such a revelation or discovery of God, as hath an exquisite tendency to please a rational taste, elevate and extend our perceptions, remove the pressures of guilt, support under a sense of pain, and particularly assist and animate us, in the pursuit of the noblest ends of our existence, and carry us on to the final destination of our nature, in its rest in the supreme and eternal good, who is the final cause of our immortal spirits. That which has the fittest tendency to carry us with the surest success to the highest end, must be esteemed the richest and most abundant good to man.

In order to know the chief good of the human kind, we must consider what we are; what are our chief springs of action; what are our principles of fruition; and what is the last end of man.

We find that there are three constituent principles, or properties, which distinguish human nature from the beasts that perish. Man has a perception of a first cause,
whom

whom we call God—he has a moral sense, or perception, of the difference between moral good and moral evil — and a lively apprehension of immortality in a future world.

But in spite of human pride man is a guilty creature ; he has swerved from his truest and noblest end ; and has infinite need of a divine revelation, to restore him to his original state, and raise him to an immortal dignity.

The gospel is adapted to this end, with the most exquisite delicacy and wisdom. It teaches us to confess the depravity of our own nature, and the rectitude and beauty of the divine ; to acknowledge the holiness of the law, and cover ourselves with shame, for all our deviations from the wise and excellent order of heaven — it inspires us with sentiments of veneration for the excellencies of God ; and obliges us to see and own the transcendent beauty of his perfections, as the object of our choicest thoughts and highest esteem.

This blessed revelation persuades us to trust in the supreme mind, and commit all our concerns in life and death into the hands of that God, who is a Being of infinite tenderness and fidelity ; it animates us

to

to a generous zeal for the honour of his perfections, when they are denied or degraded by the tongues and actions of infidels, who set themselves against him.

It teaches us to improve all our talents of nature, literature and goodness, all our power, wealth and reputation for the divine honour; and to produce the glorious fruits of knowledge and benevolence, proportionable to the advantage we enjoy; and thus to represent the beauty of God's moral perfections to mankind.

This excellent religion persuades and assists us to acknowledge our infinite distance from God, our utter unworthiness before him, and universal dependence on his vital presence, and incessant energy to preserve, enlighten and extend our powers; it teaches us to give him the highest glory, as the generous author of all our good, the source of all our blessings; to express the utmost gratitude for his beneficence; to set an extreme value on all his blessings of nature and grace; and to preserve a deep sense of the precious benefits of health, wealth, and happiness.

* See Dr. Ridgley's body of divinity, p. 1—7.

This generous religion pours a torrent of pleasure through all the mind and soul of man; it breathes eternal chearfulness into the distressed conscience; it recommends God's service as most agreeable to our faculties, most suitable to our rational powers, promotive of our best interest, full of solid satisfaction; and it sweetly constrains us to avow in the face of the whole world, that we do not repent of engaging in the service of our adorable master; that we do not wish we had pursued the paths of vice, and pleased the grand apostate, the first rebel in the world, rather than our omnipotent and good Creator, the ever blessed and immortal GOD.

**A MINIATURE PICTURE OF THE
CHRISTIAN RELIGION, OR A
VIEW OF THE BEAUTIFUL
PERFECTIONS OF CHRISTIAN-
ITY.**

The gospel is a bright discovery of a benevolent provision of happiness for man; — a provision of happiness consistent with eternal rectitude, and founded upon the invariable justice of the divine nature; a provision replete with wonder animated

mated by love, made effectual in its intentions by omnipotence, and carried on to its final issue under the conduct of the most exquisite wisdom and prudence.

This revelation gives us the best ideas of God's perfections, it unfolds God's full character, it discovers all of God at once, as far as man in his present state can apprehend.—This glorious institution teaches us the several relations of God to our world, as its almighty creator, proper owner, wise governor, generous benefactor, and impartial judge.

This divine religion asserts the original dignity and happiness of human nature, it shows the revolt of all mankind from God, and their deviation from the eternal order of beings and the beautiful fitness which the will of God has ordained to run through his universal empire.—It opens to our admiring eyes, God's infinite compassions to miserable man, and the harmonious assemblage of the divine perfections to recover us from ruin and raise us to final felicity. It gives a wonderful view of commanding authority to awe the mind, and of love to allure the heart to obedience.

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Christianity

Christianity throws open the most sublime truths to astonish and yet improve the human understanding, and elevate the mind to its highest perfection; it draws the most beautiful image of God upon the soul, prescribes the most intense adoration of man to his creator, and trains him up to the most generous devotion and the pleasures of angels.

This lovely scheme of religion presents us with the most perfect standard of beautiful and sound morals, it holds up to our view the best system of true virtue that ever appeared in the world, a system without redundancy, without defect; a system adjusted to the nature, the powers and the connections of man, and that is calculated for the perfect felicity, as well as the perfect rectitude of human nature. It likewise provides the best succours for our feeble powers, and gives the surest aids, the richest assistances to attain the glorious holiness it prescribes, and thus equally prevents a bold presumption of independence, and a cowardly indolence and dreaming inactivity, arising from a want of strength, or a consciousness of weakness.

This

This christian revelation discovers unutterable encouragement to distressed sinners in the divine obedience of the Lord Jesus Christ ; it opens a scene of the most glorious actions performed by the son of God in the nature of man ; or in other words, it shews us the blessed Jesus filled with heavenly dignity, and greatness of mind, animated by the most burning love to God and mankind, performing a regular course of the most beautiful actions and services ; or you may view his whole life as one entire grand action performed for the honour of God's moral attributes, suffering a death the most terrible and alarming with invincible resolution and fortitude, and followed with the most precious consequences to man, for it shews us that this one grand action and suffering completed in death, it shews us I say all this terminating upon us, as made rich by these meritorious actions and divine services which entitle us to the full fruition of God !

What a contrivance of God's superlative wisdom is this ? to give us all the infinite benefits arising from the glorious obedience, and most agonizing death of the highest personage in the world ! Thus by reason of our relation to him and his con-

nexion with us, we are made rich with his riches, and heirs of all God's empire by virtue of our relation to him who is the heir of all things.

This divine institution humbles the sinner and exalts the redeemer. It teaches us to form a very low opinion of the extent of our own knowledge and goodness, and to feel a deep sense of our constant and absolute dependance on God's universal agency, and a consciousness of our guilt: that we have offended the infinite majesty of heaven, and deserved his contempt and indignation. That we ought to be treated with abhorrence, and punished with the loss of all possible and infinite good through an eternal duration. In a word, this religion plainly shews us that sin is an infinite evil, as it strikes at an infinite God, exposes us to infinite loss, fixes a stain in the soul through an infinite duration. Such views of sin lay the soul in the dust at the foot of God, and teaches us to adore and love that Saviour who with almighty power and boundless love hath rescued us from eternal and overwhelming destruction.

Our

Our blessed religion ordains the most excellent business and useful employment for every day of our short life upon earth, it teaches us to fill up every hour with such generous deeds as shall follow us with honour into eternity and enlarge our glory and felicity for ever. Upon the christian plan of principles and actions, we are taught that a contemplation of the moral perfections of God, devotion to him through Christ, and unwearied benevolence to man, are the only ends for which life is worth a wish or a rational thought. Consequently

This divine system proposes to us the noblest springs of action, and directs us to the most exalted ends of our existence, it teaches us that God is the father and author of our being, that we sprang from his breath, should resemble his virtues, and tend towards him as our final rest and infinite good. This blessed gospel raises us to a daily correspondence with heaven, a sublime converse with the great father of reason, and the fountain of immortal spirits.

This precious scheme of salvation, is excellently adapted to the welfare of the souls of individual persons, to strengthen the understanding;

standing ; to brighten our genius ; refine our reason ; to enlarge the heart with benevolence ; fortify the soul with courage ; and sweeten all the devout and social affections.

This divine religion, gloriously promotes the good of all civil societies, unites all ranks of men in one blessed band of fathers, brothers, sons and subjects ; it teaches the rich to be generous parents to the poor, and the poor to be dutiful, grateful children to the rich ; it teaches kings to be fathers, and subjects to be sons, and turns all mankind into one general family of friendship and love.

NORTHAMPTON,
Jan. 1. 1768.

JOHN RYLAND.

Note, This display of the beautiful perfections of the CHRISTIAN religion will be continued in the SECOND ESSAY ON THE ADVANCEMENT OF LEARNING, and prefixed to a book now printing, entitled a Compendium of Natural Philosophy, containing Mechanics, Hydrostatics, Pneumatics, Optics and Astronomy. By John Horfley, A. M. adapted to a course of Experiments performed in Glasgow, 12mo.

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CONCERNING THE
MECHANICAL POWERS.

ANY machine or engine by which a man can raise a greater weight, or overcome a greater resistance, than he could do by his natural strength without it, is called a mechanical power. To every machine of this sort, a power is applied, in order to raise a weight or overcome a resistance. And the machine is so contrived, that the power which works it, shall move through a greater space in the same time, than the weight or resistance moves through: for without this, no advantage can be gained by it.

The power or advantage gained by any machine, let it be ever so simple or ever so compound, is as great, as the space moved through by the working power is greater than the space through which the weight or resistance moves, during the time of working. Thus, if that part of the machine to which the working power is applied, moves through 5, 10, 20, or (if you will) 1000 times as much space as the weight moves through in the same time; a man who has just strength enough to work the machine will raise 5, 10, 20, or 1000 times as much by it as he could do by his mere natural strength without it. But then, the time lost will be always as great as the power gained. For it will take 5, 10, 20, or 1000 times as much time for the power to move through that number of feet or inches, as it would do to move through one foot or one inch.

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The simple machines called mechanical powers, are fix in number, viz. the lever, the wheel and axle, the pulleys, the inclined plane, the wedge, and the screw. And of these, all the most compound engines do consist.

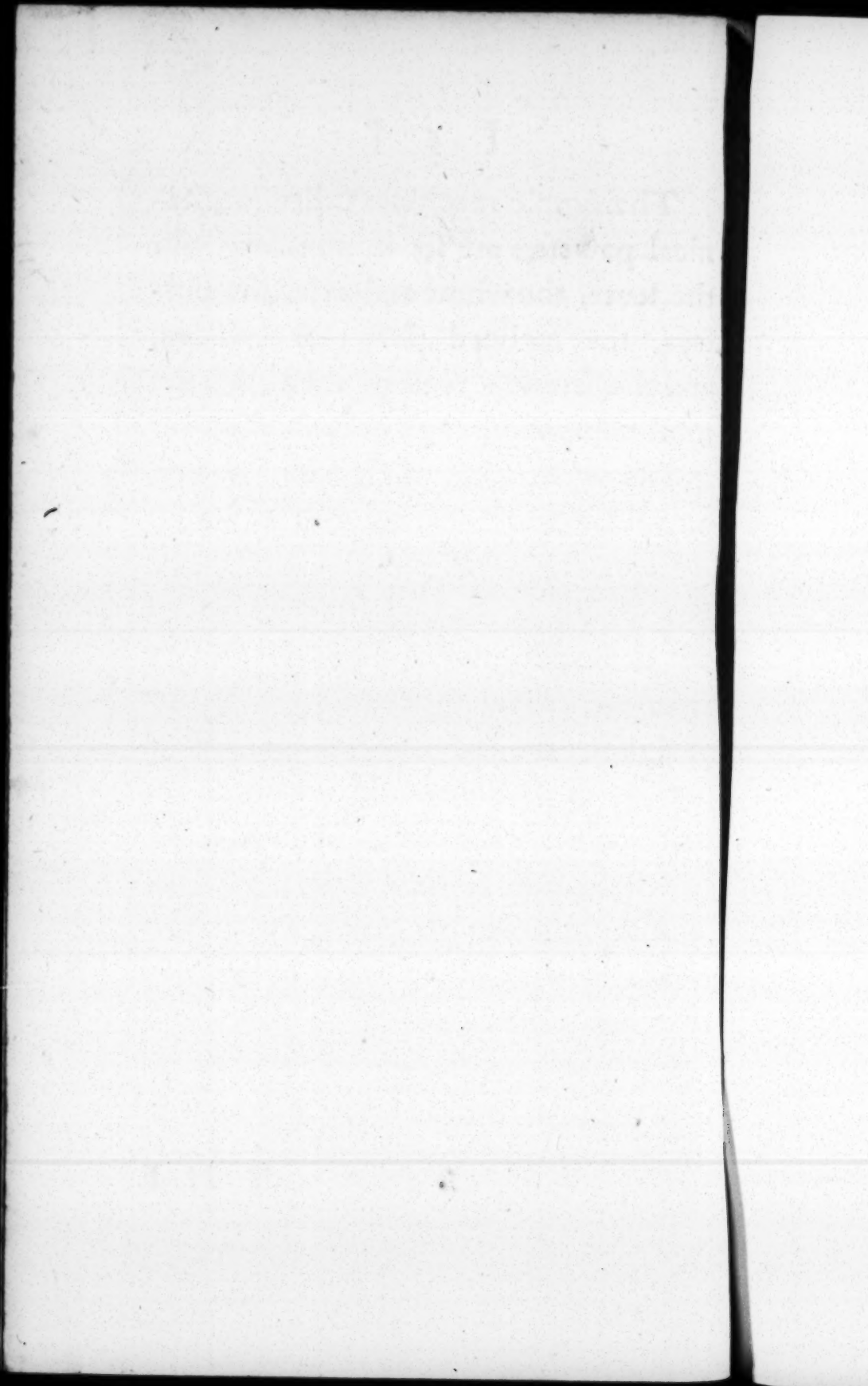


Fig. 1.

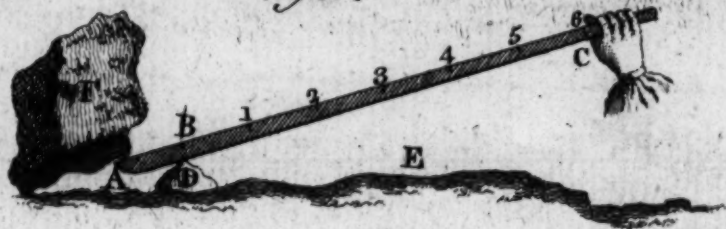


Fig. 4.

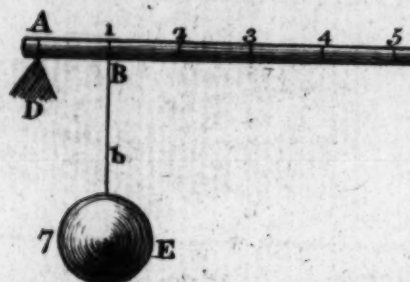


Fig. 2.

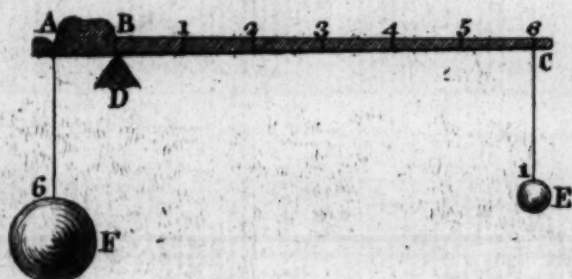


Fig. 5.



Fig. 3.

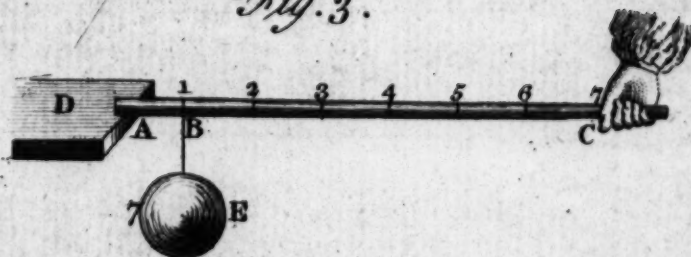


Fig. 6.

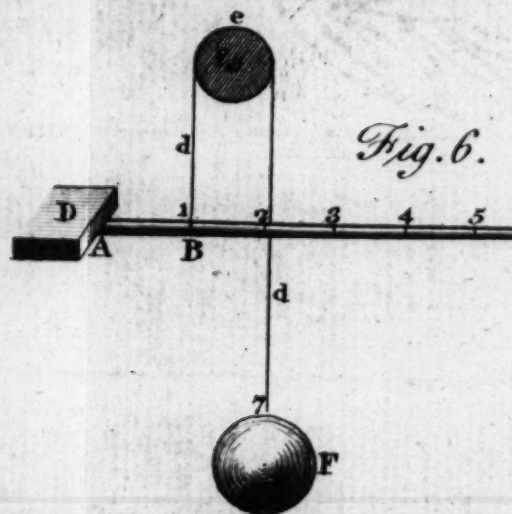


Fig. 4.

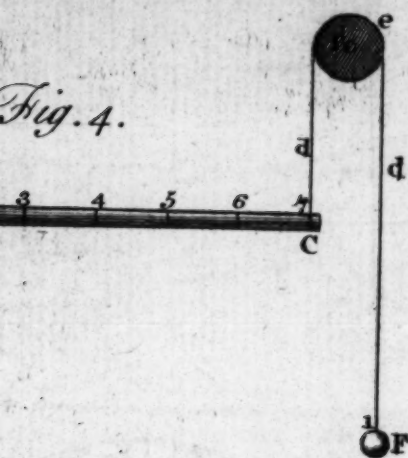


Fig. 5.



Fig. 6.

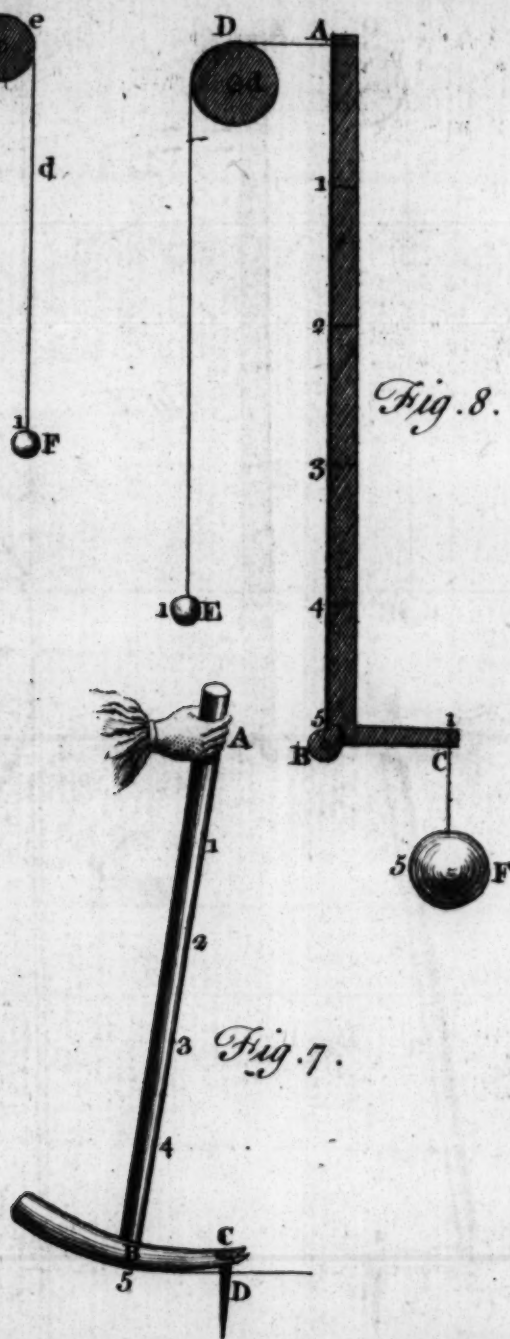
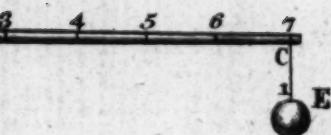
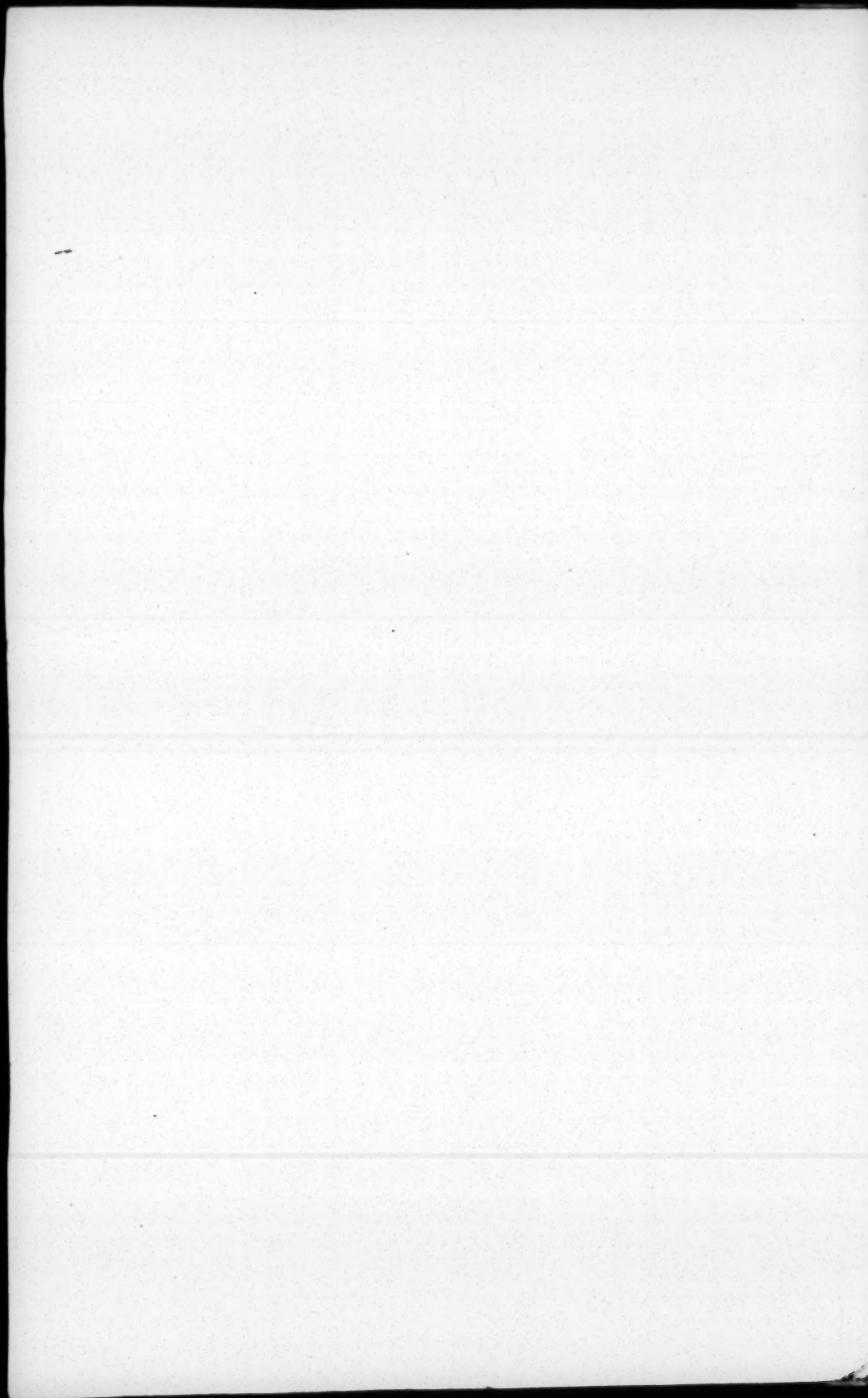


Fig. 8.

Fig. 7.



T H E
L E V E R,
O R F I R S T
M E C H A N I C A L P O W E R.

A LEVER is a bar of iron or wood, made use of for raising great weights a little way from the ground, and supporting them until ropes be put under them, to raise them higher by other machines, if required.

Fig. 1. ABC is such a bar, placed upon a stone D in the ground E. The stone must be firm in the ground, to support the lever or bar; and is called the *prop*.

The parts AB and BC, on different sides of the prop, are called the *arms*

of the lever. The end of the shortest arm AB is put below the weight F, and the hand (which is called the working power) is applied to the end C of the longest arm BC.

Here it is plain, that if the hand at C either pulls or pushes down the end C of the arm of the lever BC, the end A of the arm AB will raise the weight F.

And, by means of this simple machine, a man will be able to raise as much more weight at F than he could raise by his natural strength without any such machine, as the arm BC is longer than the arm AB: and the power or hand at C will move through as much more space than the weight F moves through, as BC is longer than AB. Hence, the power or advantage gained by this lever, or added to the natural strength of a man, is as great
as

as the arm BC is longer than the arm AB.

To prove this by experiment, provide such a bar as ABC (fig. 2.) and divide its length into any number of equal parts, as suppose 7, of which AB shall be one part, and BC the other six. Let the part AB be made so thick and heavy, as just to balance the part BC, when the bar rest on the prop D, having the part AB on the left side of the prop, and the part BC on the right side. Then hang the weight E of one ounce, on the end of the arm BC at 6, and hang the weight F of six ounces at A on the end of the arm AB; and the weight E will just balance and support the weight F which is six times as heavy. Here, E may be called the power, and F the weight. F being as much nearer the prop than E is, as E is lighter than F.

There are four different kinds of levers: the one here referred to is called a lever of the first kind, in which, the prop is between the power and the weight. The description of the other three kinds follow in order.

THE SECOND KIND OF LEVER.

In this machine, the weight is between the prop and the power. Thus, the bar ABC is supported at the end A by the table D, a weight as E is hung any where upon the bar, as at B, and the power or hand is applied to the other end C of the bar, to lift up that end, and raise the weight.

The power or advantage gained by this machine is as great as the distance of the hand from the table or prop D exceeds the distance of the
the

the weight from it. Thus, if the power or hand at C be seven times as far from D as the point B of the bar is, on which the weight E is hung, a power equal to the seventh part of the weight will support it. So that a man, taking hold of the end C of the bar or lever ABC, and pulling upward, could support seven times as much weight hanging for the point B as he could carry in his arms without such a machine; and he must raise the end C seven inches, in order to raise the weight E one inch.

To confirm this by experiment, divide the length of the bar ABC (fig. 4.) into seven equal parts, and place the end A on the prop D: then tie the string *dd* to the other end C of the bar, and put the string over the pulley *e* which turns freely round its axis *f*; the said axis being supposed to be fixed
in

in the wall of the room. This done, hang a weight *F* of one ounce to the end of the string at *I* ; and hang a weight of 7 ounces on the point *B* of the bar *AB*, at a seventh part of the length of the bar from the prop *D* ; and the weight *F* by endeavouring to descend, and raise the end *C* of the bar, will sustain the weight *E* ; so that, between these weights, the bar or lever will remain immoveable.

THE THIRD KIND OF LEVER.

In this machine, the power is between the prop and the weight. It cannot properly be reckoned a mechanical power, but rather the reverse thereof ; because a man can lift as much more by his natural strength than he can by this lever, as the distance of
the

the weight from the prop is greater than the distance of the power from the prop. So that it is the lever of the second kind reversed.

For, if the end A of the bar ABC (fig. 5.) be placed below the table D, and the bar be divided into seven equal parts, from A to C; and there be a weight of one ounce, as E hung upon the end C of this lever, and a man takes hold of the lever at B, which is only a seventh part of the whole length from the end A, and pulls upward, he must pull with a power or force of seven ounces at B to support one ounce at the end C; and then, if he raises his hand one inch higher, the weight C will be raised seven inches.

To prove this, divide the bar ABC (fig. 6.) into seven equal parts, put the end A under the table D, and tie one
end

end of the string *dd* to the division 1 at B, and tie the other end of the string at 7 to a weight F of seven ounces. Then, tie the weight E of one ounce to the seventh division at the end C of the bar, and put the string over the pulley *e* which is at liberty to turn round its axis *f*; and the weight F which acts as a power of 7 ounces to pull the lever upward, will be balanced by the weight E which is but one ounce, and pulls the lever downward with the force of one ounce. So that, if the part AB be made thick enough to balance the part BC without any weights, and the weights E and F be hung on as in the figure, they will just balance and support each other. And if the weight F be pulled one inch downward, it will raise the weight E seven inches.

T H E

THE FOURTH KIND OF LEVER.

This lever differs in nothing but its form, from the lever of the first kind : its power is the same, and its shape is represented in fig. 8. and is applicable to that of drawing a nail out of wood by a hammer.

Suppose the shaft AB (fig. 7.) of the hammer ABC to be five times as long as the iron part BC, which draws the nail D ; the part B of the hammer resting on the point 5 of the board as a prop. Then, by pulling backward the end of the shaft at A, a man will draw the nail D with a fifth part of the power that he could pull it out with pincers, in which case, the nail would move as fast as his hand does ; but with this hammer, the hand moves through
five

five times the length of the nail by the time the nail is drawn out of the wood.

To confirm this, make AB (fig. 8.) five times as long as BC, bending the bar ABC to the form of a carpenter's square. Then let the heel B turn on a pin *b*, as a fixt axis or prop, driven into the wainscot of a room, and let a string fixt at A go over the pulley D which turns on the pin *d* also fixt into the wainscot. Then hang a weight E of one ounce to the lower end of the string, and a weight of five ounces as F, to the end C of the bended lever; and these weights will balance each other. Here the axis or prop *b* is between the weight F and the power E, (whose action is at A) as in the lever of the first kind.

All scissars, pincers, and snuffers, are levers of the first kind, and the nail
which

which holds them together is the fulcrum or prop.

Bakers knives, which are fixed by a staple at the point of the blade, act as levers of the second kind, in cutting loaves. Rudders of ships, and doors turning on hinges are levers of the second kind, and so are oars of boats.

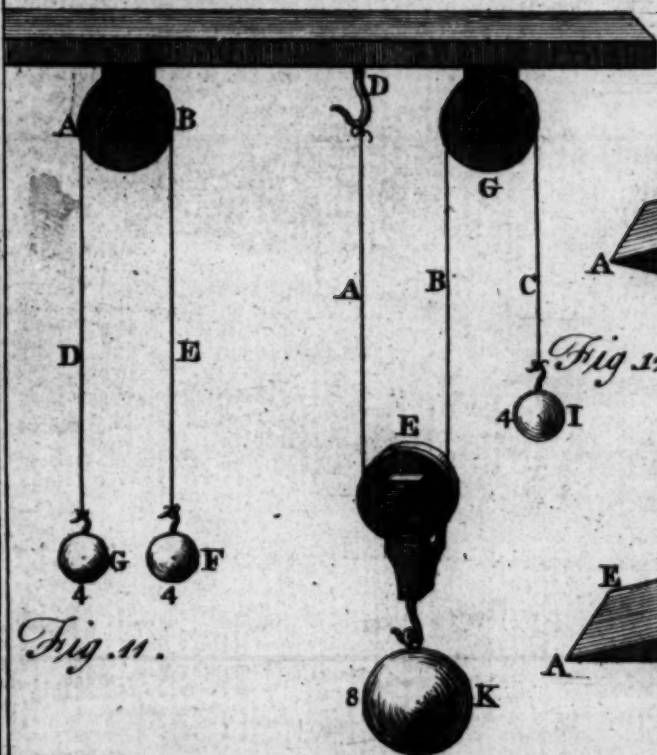
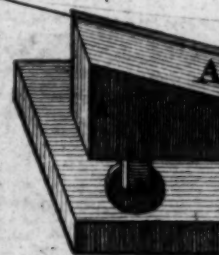
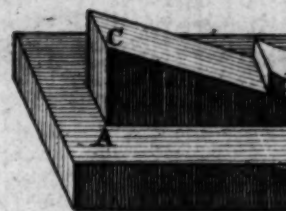
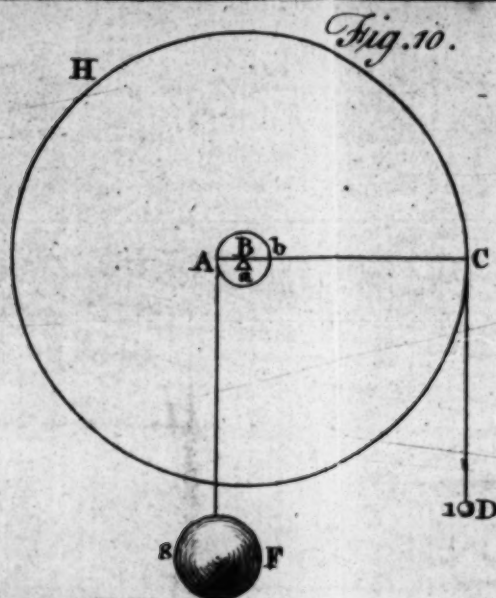
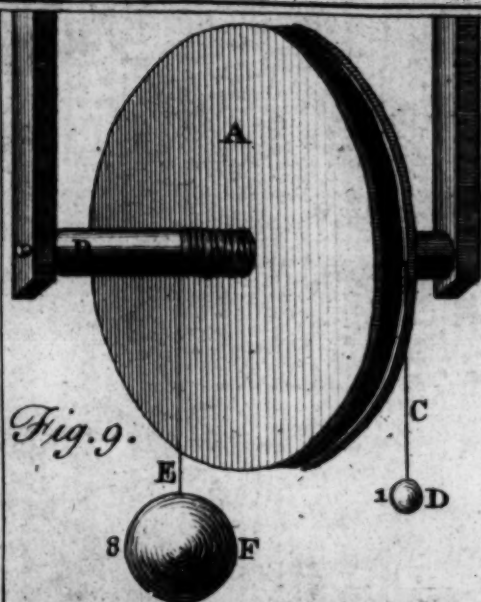
The bones of a man's leg or arm act as levers of the third kind, and so do the pinions and wheels of clocks and watches.

THE

T H E
W H E E L A N D A X L E,
O R S E C O N D
M E C H A N I C A L P O W E R.

IN this machine a cord C goes round the wheel A, and another cord E goes round the axle B, which is fixt into the wheel; so that for every time the wheel is turned round, the axle must turn round also.

A weight F (fig. 9.) is fixt to the cord E that goes round the axle, and a power is applied at D to the cord C that goes round the wheel. If the power D bears the same proportion to the weight F *that the diameter of the axle bears to the diameter of the wheel,*
the



S.

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Fig. 15.

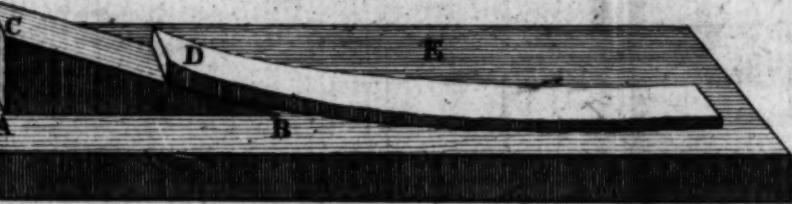


Fig. 16.

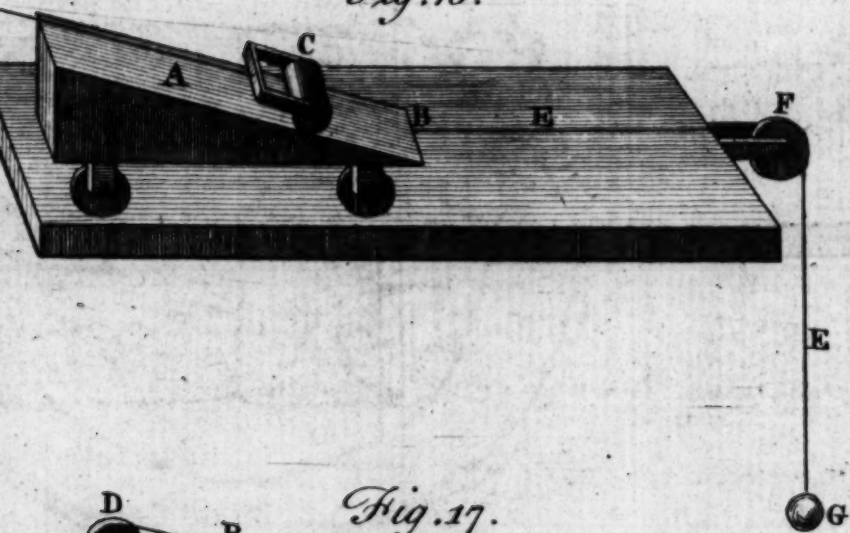
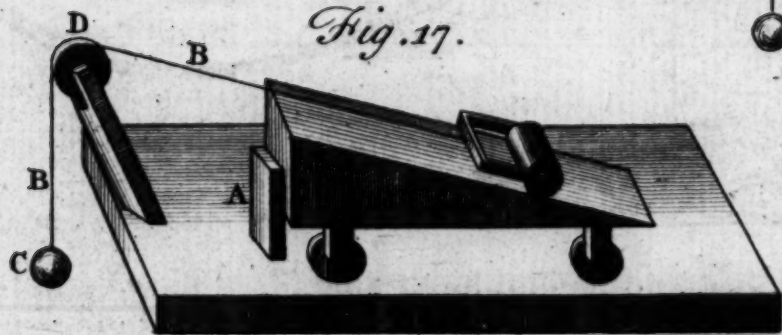
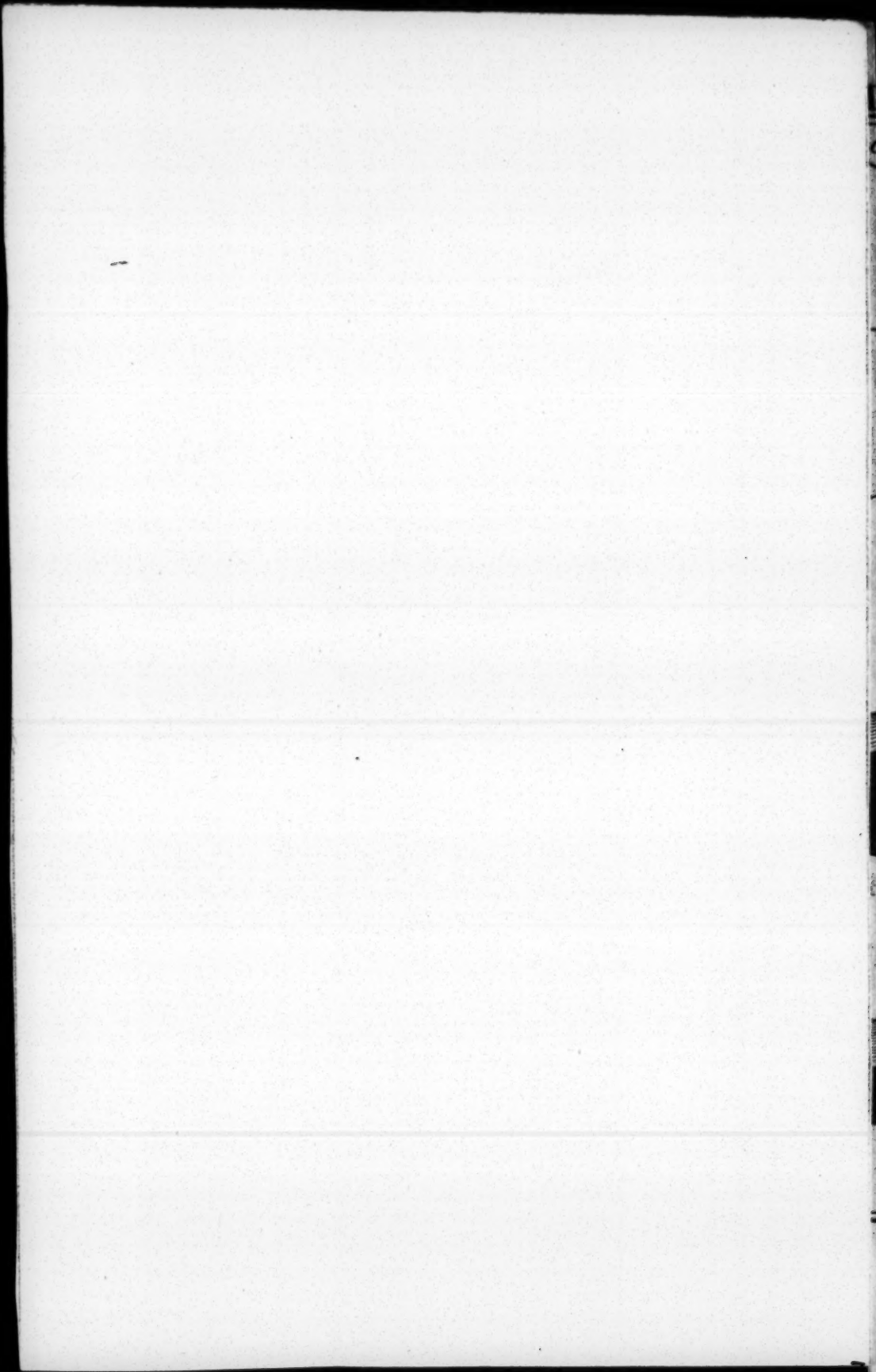


Fig. 17.



J. Myrda fecit.



the power and weight will balance each other. Thus, suppose the diameter of the wheel to be eight inches, and the diameter of the axle to be one inch; then, one ounce acting as a power at D will balance eight ounces of weight at F; and a small additional power at D will cause it to descend, and turn the wheel and its axle, and so raise the weight F. And for every inch that F rises, D will fall eight inches: *so that the velocity of the power D will exceed the velocity of the weight F as the circumference of the wheel exceeds the circumference of the axle, which we here suppose to be eight times.* And by such a machine a man pulling the cord C at D would be able to raise eight times as much weight at F hung to the cord E as he could raise by his natural strength without such a machine. Hence, the power and advantage gained by this machine is as
great

great as the diameter or circumference of the wheel exceeds the diameter or circumference of the axle.

It is easy to conceive that the power of the wheel and axle is the same with that of a lever of the first kind. For, (in fig. 10.) let HC be a wheel, and Ab its axle. Draw the straight line ABC; then, as B is the center of the wheel, AB is the semi-diameter of the axle, and BC the semi-diameter of the wheel; and here, AB may be considered as the shorter arm of the lever ABC, BC as its longer arm, and *a* the prop. Now, if BC be eight times as long as AB, a weight D of one ounce hanging from C will balance a weight F of eight ounces hanging from A.

THE

T H E
P U L L E Y,
OR THIRD
MECHANICAL POWER.

A Single pulley as AB (fig. 11.) that turns round its axis in a fixt block as C, and does not move out of its place, serves only to change the direction of the power, but gives no mechanical advantage thereto. So that a man can raise no more weight by means of this pulley than he could lift by his natural strength without it.

For, if a rope DE goes over this pulley, and has the two equal weights F and G (suppose four ounces each) hung to its ends, they will balance
each

each other ; and if either of them be pulled down, through any given space, the other will rise through just as much space in the same time : and therefore as the velocity of the weight is equal to the velocity of the power, the power must be as great as the weight to balance it.

But if (as in fig. 12.) one end of the rope ABC be tied to a fixt hook D, and the rope goes under the pulley E which turns in the moveable block F, and over the pulley G which turns in the fixed block H, a power equal to one ounce at the end of the rope C at I will balance a weight K of two ounces hung at the moveable block F. So that, where a pulley is used that will rise with the weight, a power equal to half the weight will balance it.

For the weight K of eight ounces hangs by a double rope AB, and therefore,

fore, the part A of the rope sustains one half of the weight, and the part B the other. And therefore, if a man was to take hold of the rope at B, and pull upward, he would only feel half the weight K, because the other half hangs by the part of the rope at A. But as it is more convenient to pull downward than upward, if the rope be put over the pulley G, which turns in the fixt block H, and serves only to change the direction of the pull ; a man pulling by the rope at C will raise twice as much weight at K as he could lift by his natural strength without any machine.

If there are two pullies in the lower block F, there must also be two in the upper block H ; and then, as the rope will be twice doubled in going over and under all these pullies, the weight will hang by four parts of the rope,
and

and a power equal to a fourth part of the weight will balance it. Hence, the power of this machine is as the number of parts of the rope by which the lower block F hangs; and this will be always equal to twice the number of pulleys in that block.

THE

For (fig. 15.) if a moulding D was to be split off from a thick plank E, by driving the inclined plane ABC between

tween the plank and moulding, the moulding will be as much easier separated from the plank by this means, than it could be pulled off by a cord fixed to a staple in the moulding at D, as BC is longer than AC.

To prove this by experiment, let the inclined plane A (fig. 16.) run upon wheels, and be drawn forwards by means of a weight G, to which the line EE is fixed, and also to the inclined plane at B; the line going over the fixed pulley F. Let one end of the line D be fixed to a hook in the wall, at five or six feet from the inclined plane, in such a manner, that when the other end of the line is tied to the frame of the roller C the line may be parallel to the acting side A of the plane. Now, if the weight G be as much lighter than the roller C and its frame, as the height or thickness *a*,
of

of the plane is less than the length of the side A , the plane will rest under the load C , so as the load can neither make it run back, nor can the weight G draw it forward. So that, if the length of the side A be four times as great as the perpendicular height a , a power at G equal to one fourth part of the weight of the load C will balance the plane under it.

If you set the inclined plane (fig. 17.) against the piece A to keep it from moving backward, and let the roller be drawn by the line BB going over the fixed pulley D by means of the weight C . If C be as much lighter than the roller as the inclined side of the machine is longer than the machine is thick at A , the load will be supported on the plane by the power of the weight C . And thus we find, that in drawing a cart

or waggon up-hill, if the power of the horses be proportioned to the weight of the waggon as the perpendicular height of the hill is to the length of its side, the waggon will be kept from running back. And as much additional-power as will overcome the friction of the axles, will draw the waggon up the hill.

Fig. 18.

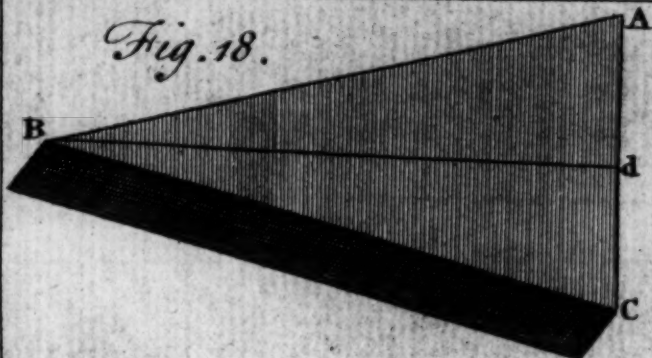


Fig. 21.

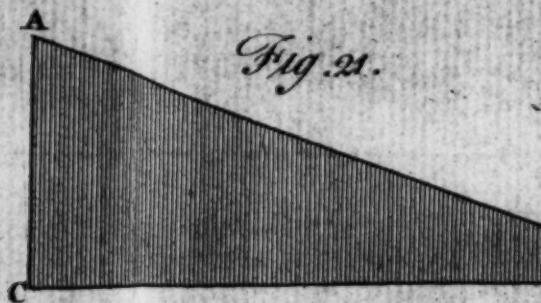


Fig. 19.

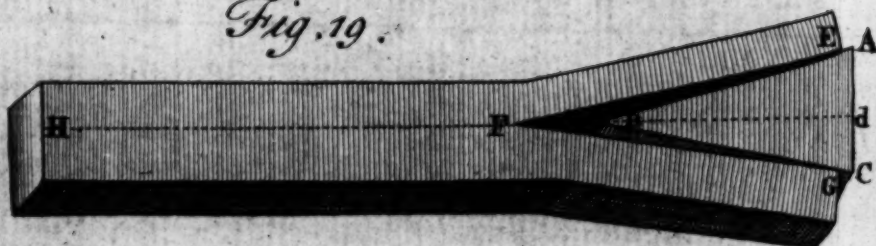


Fig. 23.



Fig. 24.

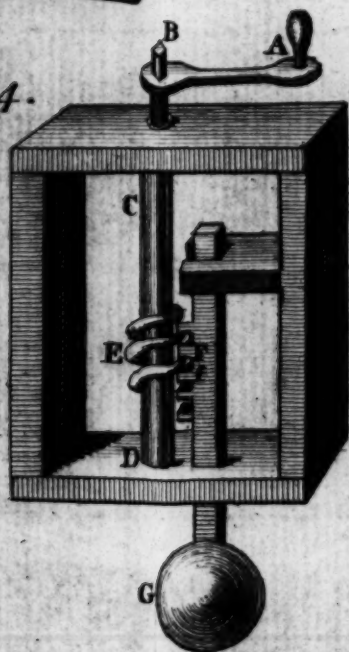


Fig. 20.

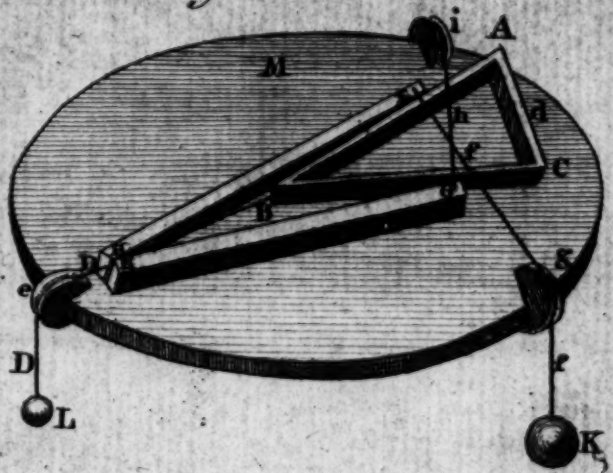




Fig. 22.

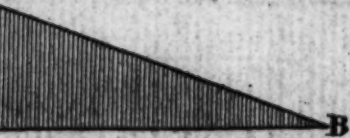


Fig. 23.

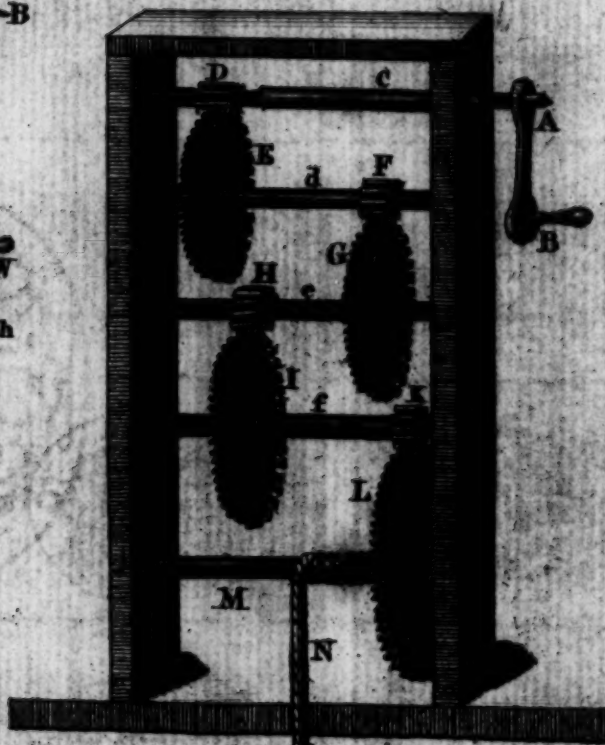


Fig. 25.

M E

I F

ABa

their

wed

T

pow

sistan

as th

back

resist

BC

the p

T H E
W E D G E,
OR FIFTH
MECHANICAL POWER.

IF two inclined planes (fig. 18.) which are equal and similar, as ABd and CBd be joined together at their bases Bd , they will become a wedge as ABC .

Therefore, in cleaving wood, the power of the wedge will be to the resistance of the wood on the side BC as the length of that side is to the half back Cd of the wedge; and as the resistance of the wood against the side BC is to the half back Ad . That is, the power or advantage gained by the

C 3 wedge

wedge is as great as the side BC or BA exceeds the half back Ad or Cd . Or, putting the whole together, as great as the length of both the sides AB and BC exceeds the length of the back AC where the blow is struck by the hammer or mallet.

For, in fig. 19, before the wedge ABC enters the wood EHG that is intended to be cloven, the parts EF and GF are in contact; but when the wedge is driven into the wood, the part G is removed as from d to C, and the part E is removed as from d to A: so that, the velocity of E or G (going off obliquely) is to the velocity of the wedge, as the length of the side of the wedge BA or BC is to the half back dA or dC . And, in this, as well as in all the foregoing mechanical powers, the power or advantage gained is

is as great as the velocity of the power exceeds the velocity of the resistance.

To prove this by experiment, let the two pieces of wood (fig. 20.) EH and GH be joined at HH by band or hinge, and be drawn together by the small cords *Efgf* and *Ghi*, going over the pullies *g* and *i*, and having weights as *K* at the lower ends of the cords, (the weight on the line *Ghi*, equal to the weight *K*, being hid from sight by the table *M*) and let the light wedge ABC be drawn into the wood EHHG by means of the weight *L* hanging at the cord DDB, fastened to the wedge at *B*, and going over the pulley *e*. If the weight *L* be in the same proportion to the weight *K* as the half back *Ad* of the wedge is to either of its sides *AB* or *CB*, the weight *L* which acts as a power for making the wedge go into the wood, will balance the

weight *K* which pulls the side *EH* of the cleft *EHHG*, as a resistance, against the side *AB* of the wedge ; and will also balance a weight equal to *K* hanging at the cord *Ghi*, and pulling the side *GH* of the cleft as a resistance against the other side *BC* of the wedge.

THE

T H E
S C R E W,
OR SIXTH
MECHANICAL POWER.

IF a piece of paper be cut into the shape of an inclined plane ABC (fig. 21.) and wrapped round and round the cylinder AB (fig. 22.) from the perpendicular AC to the point B, the side CB being still kept upon itself in wrapping, the inclined side AB will form a spiral or screw as *abcd* around the cylinder AB.

If these spirals be cut deep into the wood, as at *abcd*, as in fig. 23, and the gudgeons *g* and *h* of the wood do turn in a frame; if the cylinder AB

be turned round and round by the winch *W*, the spirals or threads of the screw *abcd* will have a progressive motion, as from *A* toward *B*, advancing through the space *ab*, or *bc*, or *cd*, always in being once turned round.

And, if the top of the strong spring *D* (whose foot is fixed into the heavy and immoveable block *F*) be put between any two of the screw-threads, as at *e*, and then if the screw be turned once round, the top of the spring will be moved from *e* to *f*, through a space equal to the distance between any two of the threads *ab* or *bc*; and the spring, which acts as a resistance against the power that turns the screw, will be bent into the form *GEf*.

Now, since the resistance moves only from *e* to *f*, in the time that the screw is turned once round, it is plain, that the power or force gained by the screw

is

is as great as the circumference of the cylinder AB on which the spirals are cut, exceeds the distance or space between the neighbouring spirals, if the screw be turned round by hand, taking hold of the end of the cylinder at B. But, as the screw is never turned in that manner, but by means of a lever or winch W, the power of the screw is increased as much as the length of the lever from *b* to the handle W exceeds the semi-diameter of the cylinder AB.

Thus, in fig. 24. the weight G is fixt to the end of the rack F whose teeth work in the screw E belonging to the axis CD, on the top of which is the handle or winch AB, which being turned once round, will turn the screw one round, and lift the rack and weight through the space of one tooth, as from F to *f*. Now, suppose this space to

to be one inch, which is lifted at one turn, and the length AB of the handle to be seven inches ; then the circle described by the power that moves the handle will be forty-four inches in circumference. So that, as the velocity of the power is forty-two times as great as the velocity of the weight, a man could raise forty-two times as much weight [allowing for friction] by this engine as he could do by his natural strength without it.

A

POWERFUL ENGINE

F O R

RAISING VERY GREAT WEIGHTS.

ON the axis C of the winch AB is a pinion D turning the wheel E, on whose axis is a pinion F turning the wheel G, on whose axis is a pinion H turning the wheel I, on whose axis is a pinion K turning the wheel L, on whose axis M the rope N coils or winds (as the machine is turned by the winch) and draws up the weight O.

Now, suppose each pinion to have eight leaves (sometimes called teeth) and each wheel to have eighty teeth, it is plain that the pinion turns ten times

times round for once that the wheel can turn round in which the pinion works. Therefore, the pinion D will make ten revolutions for one of the wheel E and pinion F; the pinion F will make ten revolutions for one revolution of the wheel G, which wheel, together with the pinion H will make ten revolutions for one of the wheel I and pinion K, and the pinion K will make ten revolutions for one revolution of the wheel L and its axle M. And these four tens being multiplied into one another give a product of 10000. So that the winch AB must be turned round ten thousand times, in order to make the wheel L turn once round, which will only raise the weight O through as much space as it takes length of the rope N to go once round the axle M.

Hence,

Hence, if the axle C was to be turned round by hand, without a winch, a man could raise ten thousand times as much weight by the rope coiling round the axle M as he could do if it coiled round the axle C. But if he makes use of a winch as AB, of which the length AB is ten times as great as the semidiameter of the axle C, the power of the engine will become ten times as great as before; and ten times ten thousand is an hundred thousand: so that, by this engine a man could raise an hundred times as much weight as he could do by his natural strength without it: and, for every inch that the weight rises the handle B of the winch would move through an hundred thousand inches, or almost 2778 yards.

Supposing all the axles equally big as the winch used, the rope going
round

round the axle C would enable the man to raise ten times as much as he would do without it: round the axle *d* 100 times as much; round *e* 1000 times; round *f* 10000 times, and round *M* 100000 times. So that the power may be increased at pleasure by machinery; but we see it may be made so great as to be useless, on account of the time that would be lost in working it: for the time lost is always as great as the power gained.

PART THE SECOND.

G E O M E T R Y,

BY SCALE AND COMPASSES.

T R I G O N O M E T R Y,

MEASURING OF HEIGHTS AND
DISTANCES.

THE SECOND

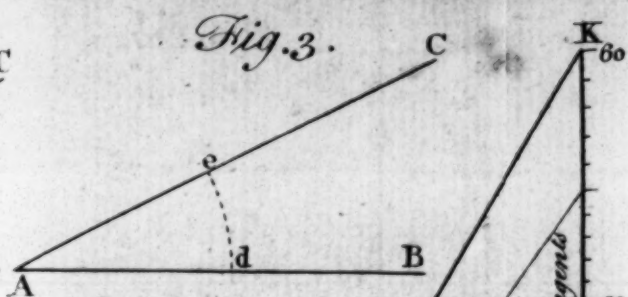
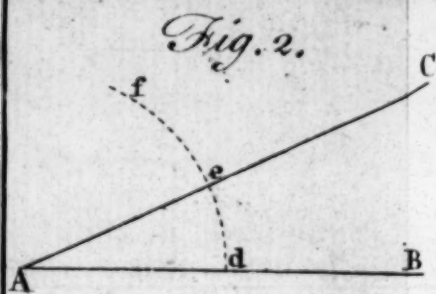
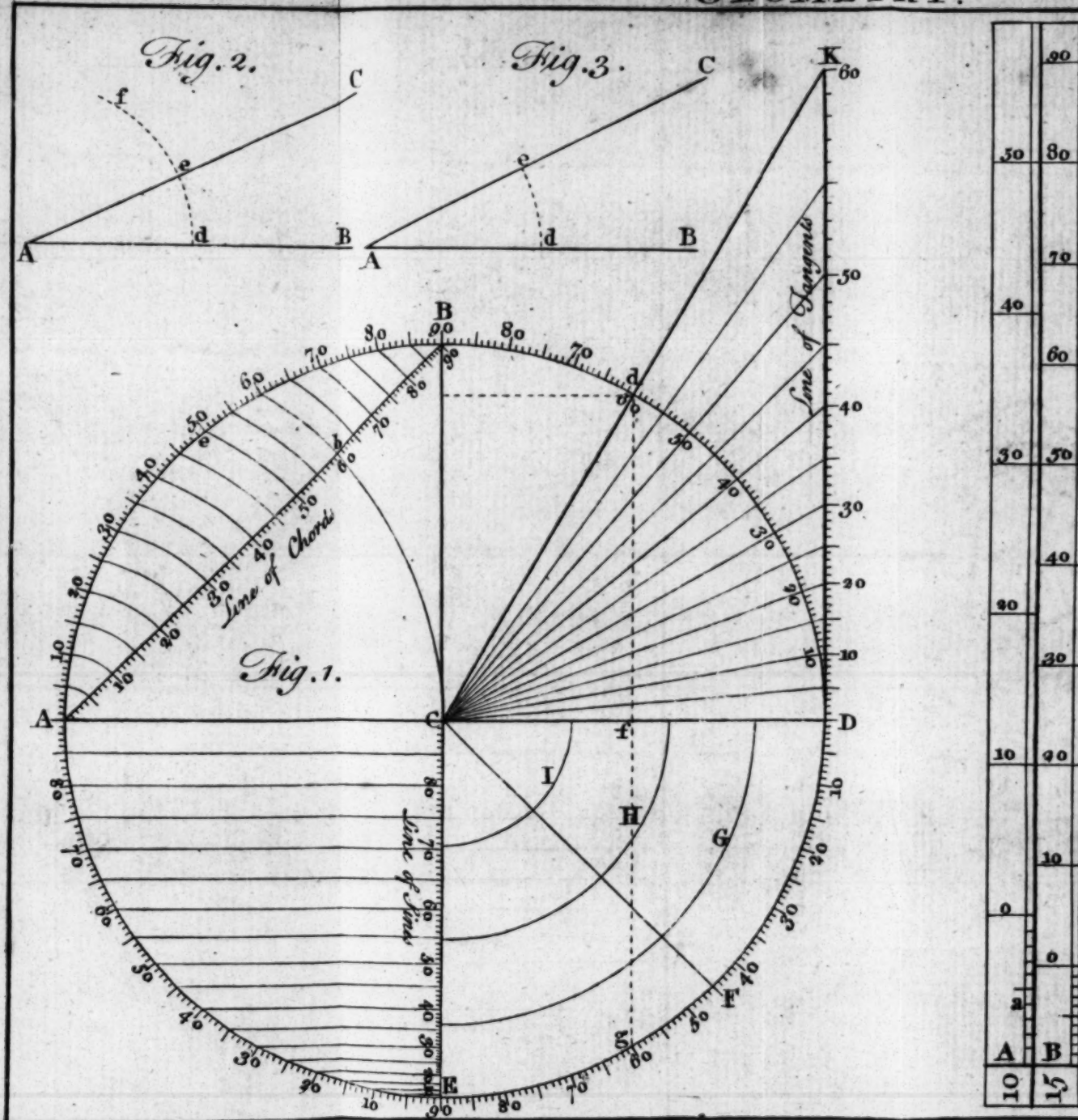
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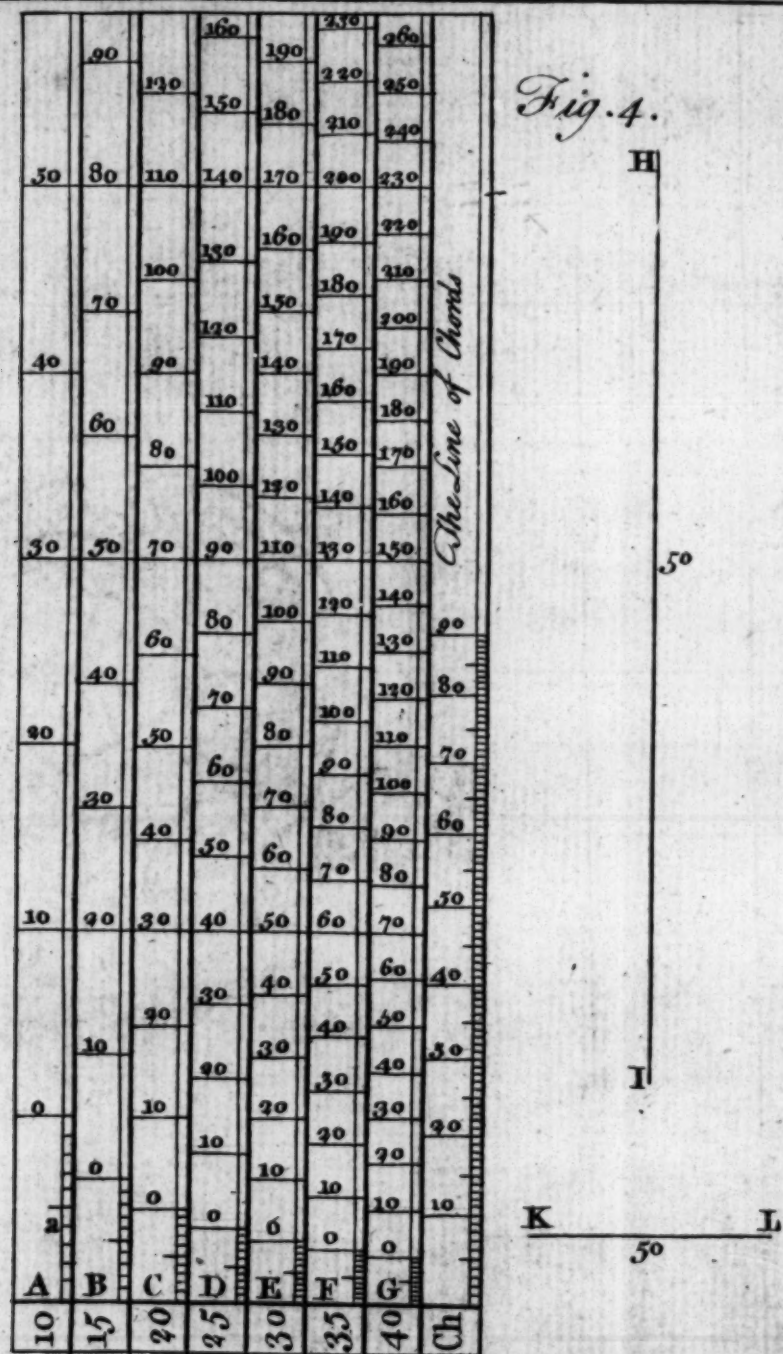
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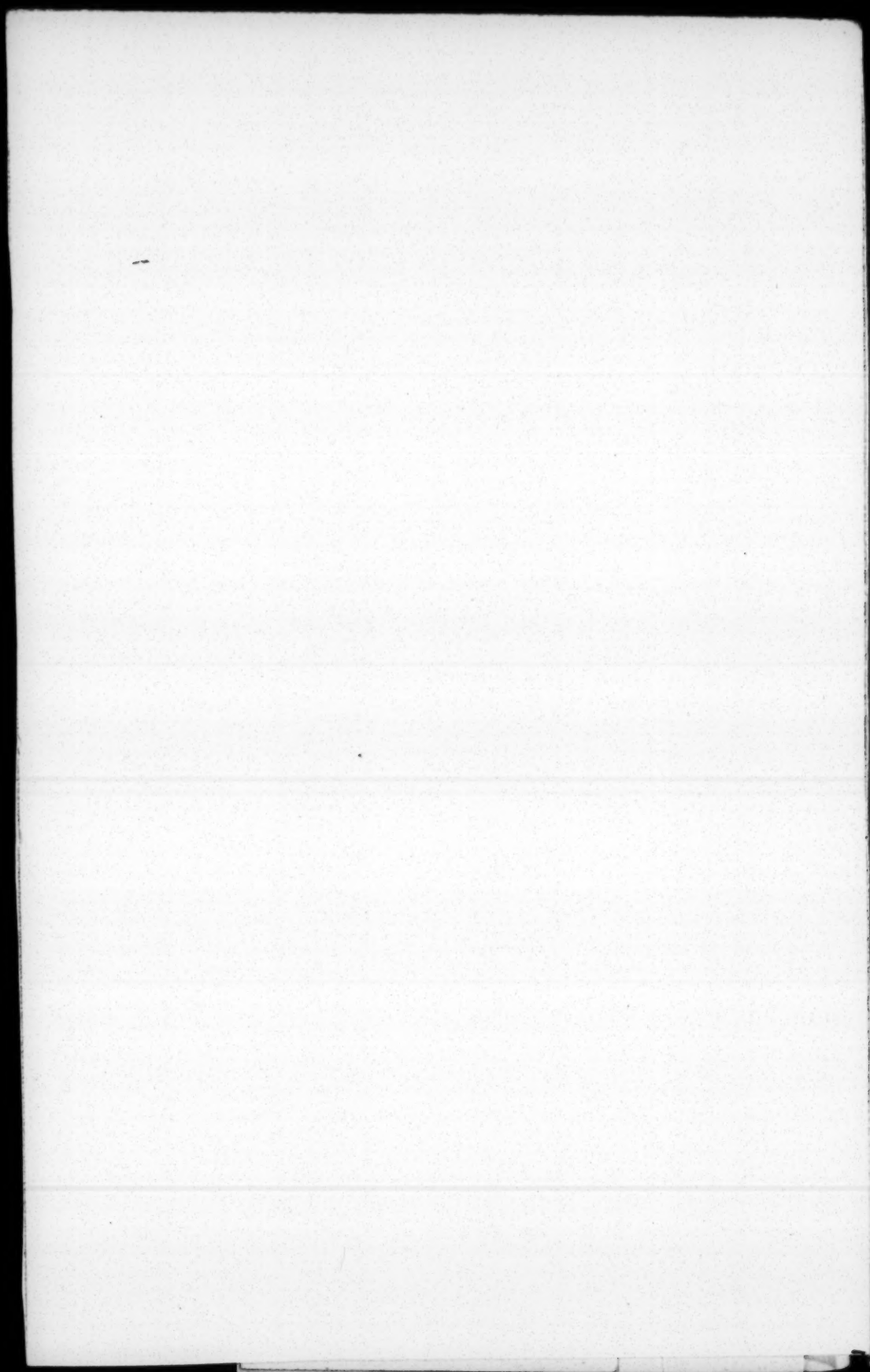
DISTANCES



10	A	0	10	0	10
		2		0	
				10	
				40	
				20	
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				30	
				40	
				60	
				70	
				80	
				50	
				90	

Fig. 4.





T H E
CONSTRUCTION
O F
ANGLES, SINES, TANGENTS,
AND CHORDS.

FIG. I. EXPLAINED.

EVERY circle, great or small, is divided (or supposed to be divided) into 360 equal parts, called degrees. Thus, the quadrant DE of the large circle ABDE contains 90 degrees, and so do the smaller quadrants G, H, I: and 4 times 90 is 360.

An angle is the space intercepted by two lines, as CD and CF, meeting one another in the center of the circle
at

at C: and its measure is the number of degrees contained in the arc DF, (as suppose 45) which is the same number as is contained in the arc G, or H, or I, bounded by the lines CD and CF. So that, the angular point C where these lines meet, is always supposed to be in the center of a circle; and the measure or quantity of the angle is the number of degrees in the circumference of the circle intercepted between the two points (as D and F) where these lines meet or cut the circle.

The diameter of a circle is a straight line, as ACD, passing through the center C of the circle, and meeting its periphery in two opposite points, as A and D.

The radius of a circle is half its diameter, as CA or CD.

The

The chord of an arc is a straight line drawn from one extremity of the arc to the other. Thus, $A\bar{b}B$ is the chord of the arc $A\bar{e}B$: and as the arc $A\bar{e}B$ contains 90 degrees, its chord $A\bar{b}B$ contains the same number also. And if one foot of the compasses be constantly kept in the point A , where the arc and chord meet at one end, and the other foot be opened successively to all the 90 degrees of the arc, and these distances of opening be transferred from the arc to the chord line, as in the figure, the chord line will be divided into 90 degrees.

N. B. Sixty degrees on the chord line, taken from A to b , are equal to the radius of the circle from which the line of chords is made. Thus, $A\bar{b}$ is equal to AC .

The right line of an arc is half the chord of double that arc. Thus, df is

is the right sine of the arc Dd ; and is half of Dfg , which is the chord of the arc dDg . To make a line of fines as for the 90 degrees of the arc AE , draw straight lines, parallel to the radius AC , from every degree of the arc AE to the radius or semidiameter CE , and they will divide CE into a line of fines, as in the figure.

A tangent is a straight line as DK , touching the circle into any given point as D . It may be divided into degrees by straight lines drawn from the center C through the degrees of the arc DB , as in the figure. But you can never get to the 90th degree on the line DK , because it is parallel to the radius CB . So that the tangent of 90 degrees is infinite.

PROBLEM

P R O B L E M I.

To lay down an angle of any given number of degrees less than 90, as suppose of 25 degrees, fig. 2.

Draw the straight line AB, and let the angular point be at the end A. Open your compasses from A to *b* (fig. 1.) that is, from the beginning of the line of chords to the 60th degree thereof: and with that extent, setting one foot of the compasses in the end of the line at A (fig. 2.) with the other foot describe the arc *def*. Then, setting one foot of the compasses in the beginning of the line of chords, extend the other foot to 25, the given number of degrees thereon: and, with that extent, set one foot in the end of the arc at *d* (fig. 2.) in the line AB, and

and make a mark with the other foot as at *e*, in the arc *def*. Lastly, from *A*, draw the straight line *AeC*, through the mark *e*; and the line *AC* will make an angle of 25 degrees with the line *AB* as was required.

N. B. Where an angle is marked by three letters, as *CAB*, the middle letter *A* always denotes the angular point, or meeting of the lines which make the angle.

P R O B L E M II.

To measure the quantity of an angle (as *CAB* in fig. 3.) by the line of chords.

With the chord of 60 degrees (that is, by taking 60 degrees of the line of chords in your compasses) set one foot in the angular point *A*, and with the
other

other foot describe the arc *de* from one leg (or side) of the angle to the other : then, setting one foot in the end *d* of the arc, in the line AB, extend the other foot to the other end of the arc at *e*, in the line AC. Lastly, apply that extent to the line of chords, from the beginning of the line toward 90 ; and the number of degrees in the chord line that are intercepted between the points of the compasses will be the measure of the angle CAB, as was required. Which measure, in fig.3. will be found to be twenty-eight degrees.

P R O B L E M III.

To make scales of equal parts, for measuring lines ; or for laying down lines which shall represent given distances taken in feet, or yards, or miles, &c. fig. 4.

Draw several straight lines on a flat smooth piece of box-wood, and, at one end, place the numbers 10, 15, 20, 25, 30, 35, 40, as in the figure.

Set off a whole inch at A, two-thirds of an inch at B, half an inch at C, four tenths of an inch at D, one third of an inch at E, three tenths of an inch at F, and one quarter of an inch at G ; and divide the several lines ABC, &c. into as many of these spaces as they will contain. Then divide each of the first spaces as ABC, &c. into
ten

ten equal parts, and put the numeral figures to them. So shall the lines or scales ABC, &c. be divided in such a manner, as that one inch shall be contained in ten parts or divisions of A, in 15 of B, in 20 of C, in 25 of D, in 30 of E, in 35 of F, and 40 of G. The line of chords may be taken from fig. 1. and inserted on this scale.

The equal divisions either of the lines A, B, C, D, E, F, G, may be taken for feet, or yards, or miles, in plotting or measuring of any figure. And as the first space at each of the above letters contains ten equal parts, all the other spaces being equally large in each particular line, is supposed to contain ten equal parts also.

To take off any given number of parts with your compasses, from either of these scales, as suppose 26 from the scale A, which contains ten parts in an

D 2 inch

inch, set one foot of the compasses in 20 on that scale, and extend the other towards A, so far, as till it reaches the sixth division counted from 0 to *a*, and then you will have the given number of parts between the points of the compasses.

In plotting maps or figures so that a small part may take up a large share of room on paper, the scales A or B may be used; but where a great deal is intended to be put in little room, the scales F or G are to be made use of.

Thus, suppose I wanted to lay down 50 feet of distance, and had about as much space allowed for it as from H to I. I take that extent in the compasses, and find by trial that it will agree with 50 parts of the scale A. But if I had no more space than KL for representing that distance, I find by trial, that I must lay it down from the scale G.

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Fig. 5.

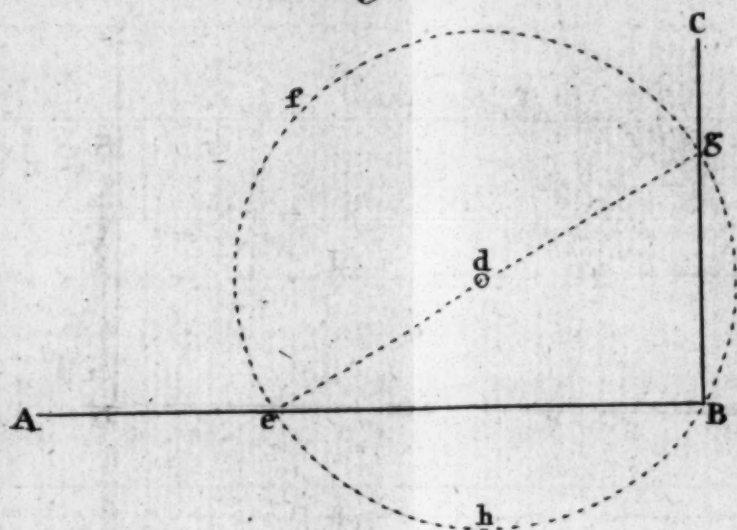


Fig. 7.

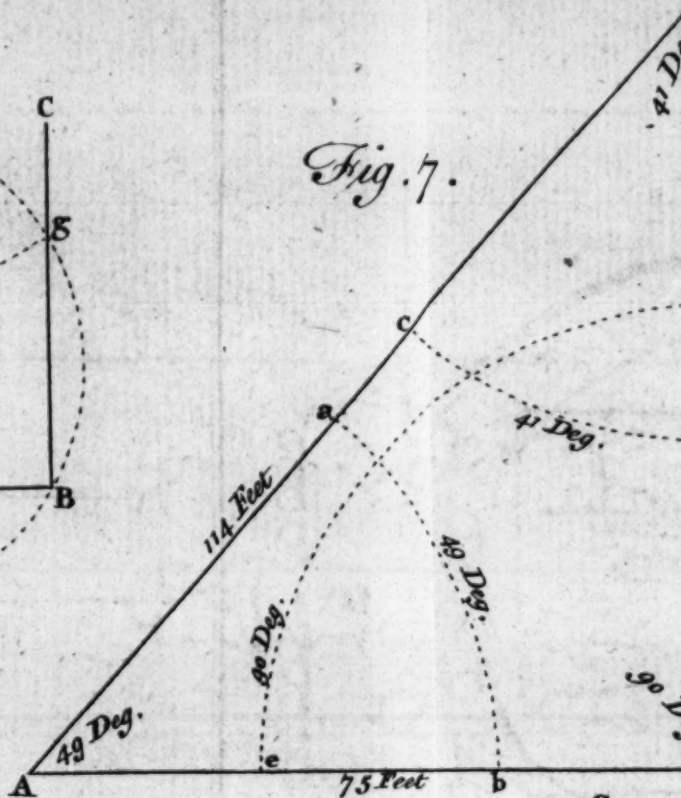


Fig. 6.

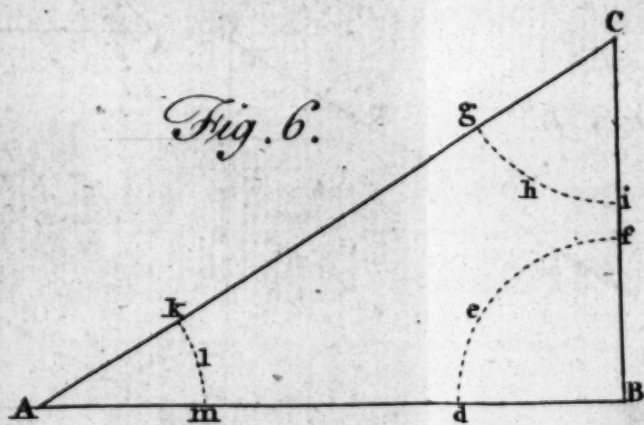
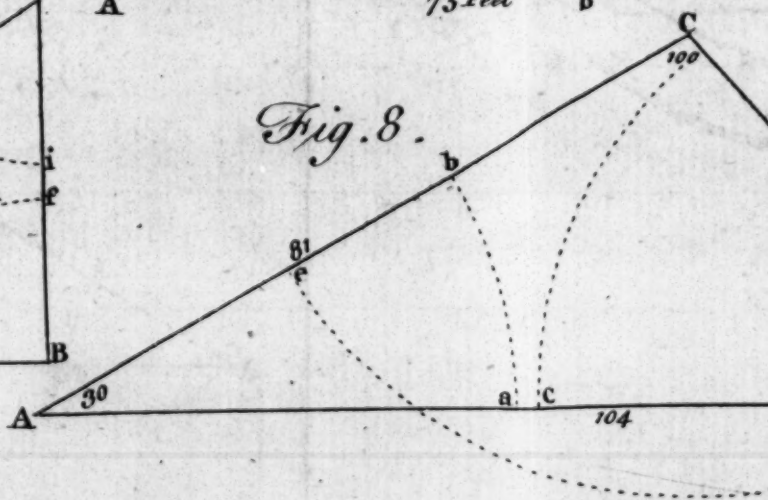
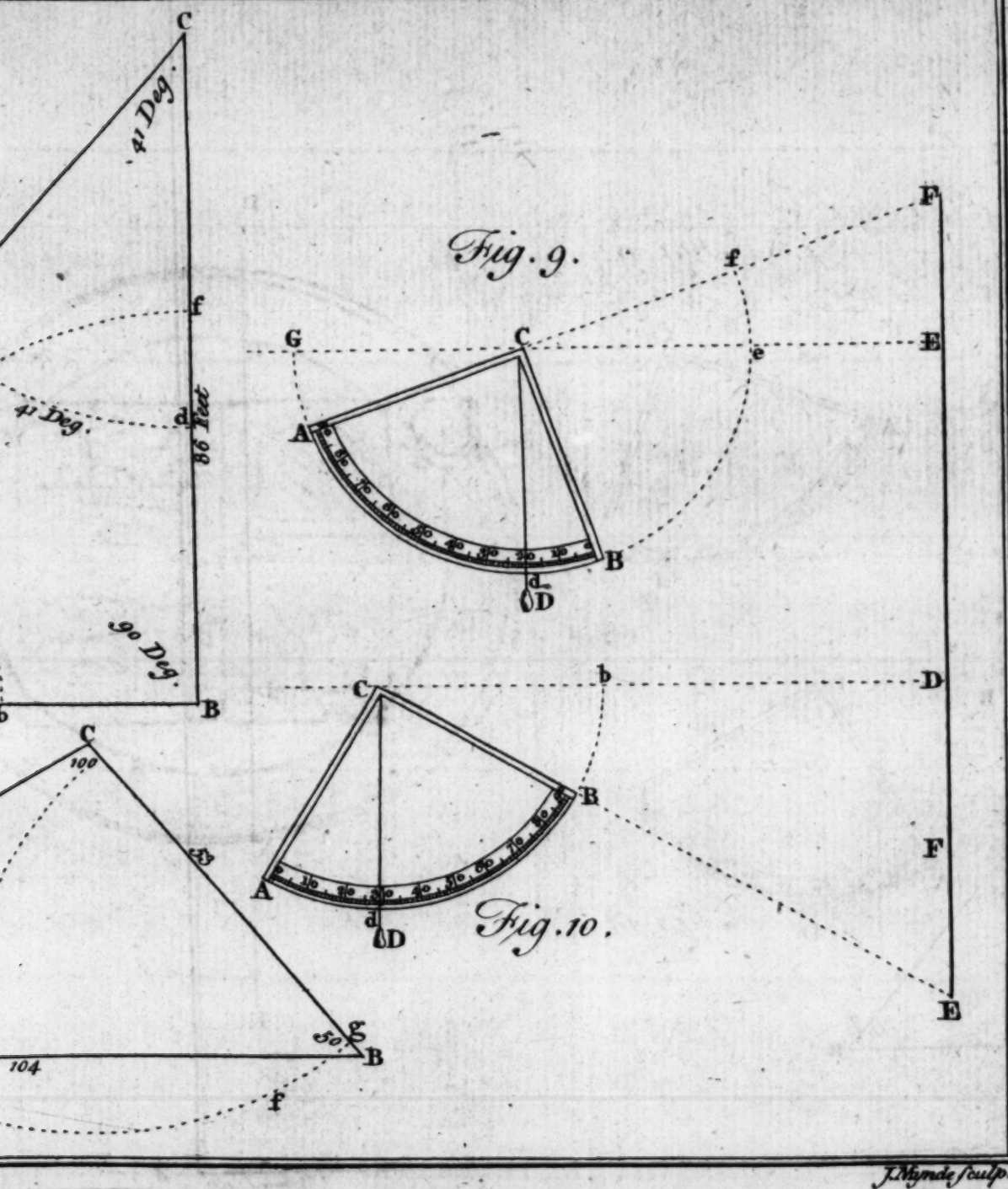
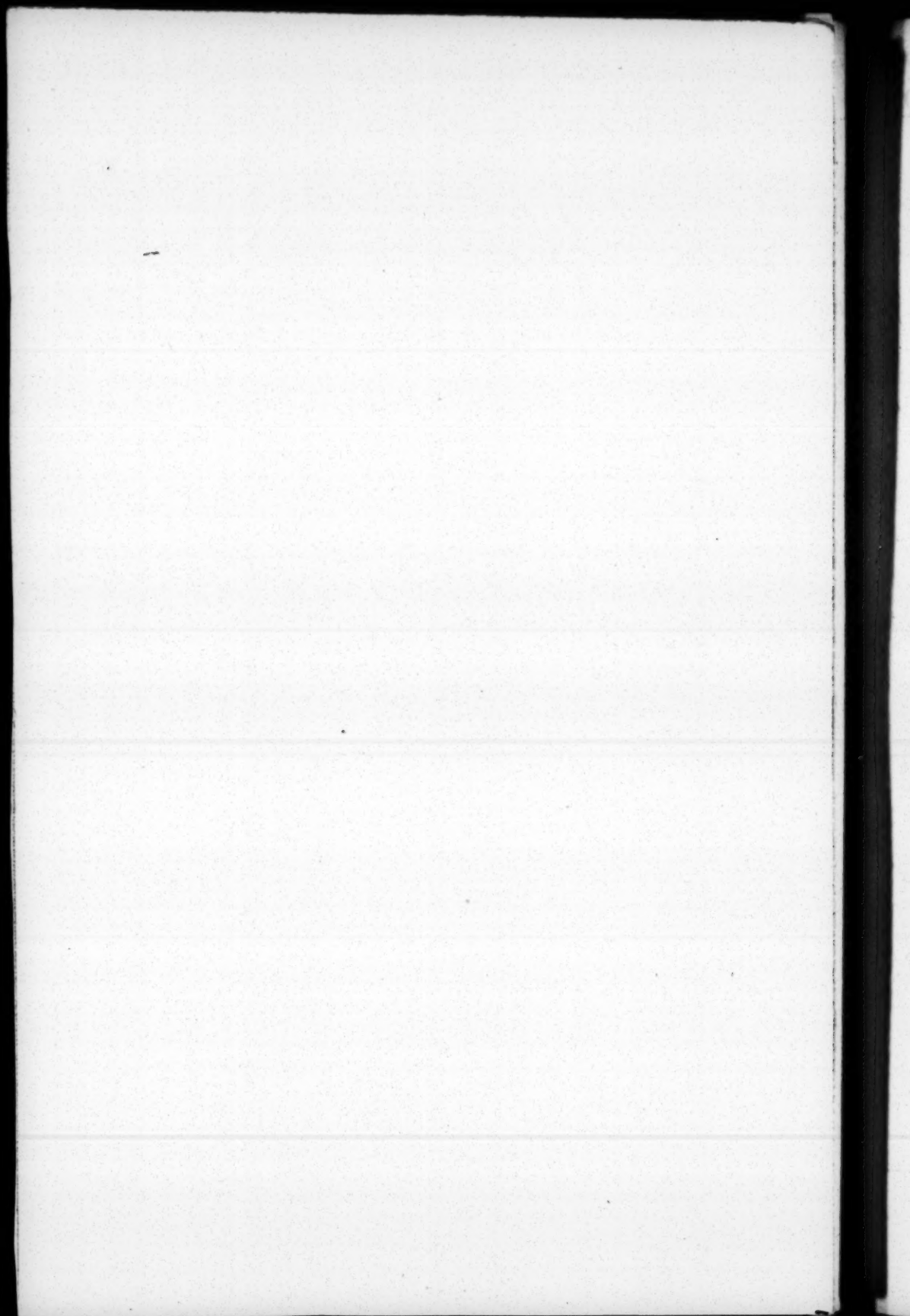


Fig. 8.







and which-ever scale is begun with, the whole map or figure must be drawn by that scale.

P R O B L E M IV.

To raise a perpendicular BC on the end of B of a given straight line AB
fig. 5.

Open the compasses to any convenient width, and setting one foot in the end B of the line AB, let the other foot fall any where above the line (no matter where, in reason,) as at *d*, and make a mark there. Then, without altering the compasses, set one foot in the point *d*, with the other foot describe the circle *efgb*; and, laying the edge of a ruler to the intersection *e* (of the circle with the line AB)

D 3

and

and thro' the point *d*, draw the diameter *edg*. Lastly, laying a ruler to B, at the end of the line AB, and to the end *g* of the said diameter, draw the right line BgC, which shall be perpendicular to the line AB, as was required.

DESCRIPTION OF A RIGHT ANGLED PLAIN TRIANGLE.

The side AB (fig. 6.) is called the base, the side BC the perpendicular, and the longest or oblique side AC the hypotenuse.

The angle at B is called a right angle, which contains 90 degrees ; for as BC is perpendicular to AB, the point B may be made the centre of a quadrant *def*, or quarter of a circle, containing 90 degrees. The angles at A and C are called acute angles, because each of them is less than 90 degrees :
for

for, if they be made the centres of the arcs *klm* and *ghi*, neither of these arcs contain 90 degrees ; but both of them taken together always do.

Thus, if the angle at A contains 31 degrees, the angle at C contains 59, which being added together make 90. And as the right angle at B contains 90, all the three angles taken together contain 180 degrees.

And hence it is, that if either of the acute angles of a right angled triangle be given, if its quantity be substracted from 90 degrees, the remainder will be the quantity or number of degrees in the other acute angle.

SOLUTION OF THE SEVERAL CASES OF RIGHT ANGLED PLAIN TRIANGLES.

N. B. In all the following seven cases, we shall keep by the scale C (fig. 4.) in measuring the sides of the triangle; and by the line of chords (fig. 4.) in measuring the angles; and shall make the triangle (fig. 7.) serve for all the cases.

C A S E I. F I G. 7.

The two acute angles at A and C, and the base AB, being given, to find the perpendicular BC.

In the triangle ABC the given angle at A is 49 degrees, and the given angle

gle at C is 41 degrees, and the base AB is 75 feet. *Ques.* The number of feet in the perpendicular BC ?

Make AB equal to 75 parts of the scale C (fig. 4.) and make BC perpendicular to AB by Prob. IV. Then, setting one foot of the compasses in the beginning of the line of chords, extend the other foot to 60 degrees (which is called the radius, or chord of 60) and with that extent, setting one foot in A (fig. 7.) sweep the arc *ab* with the other foot, and taking 49 degrees from the line of chords in your compasses, set that extent from *b* to *a*, and through the point *b*, from A, draw the line *AaC*, meeting the perpendicular at C. Then, taking the line BC between the points of your compasses, apply that extent of the compasses to the scale C (fig. 4.) and you will find it to be 86 parts or divi-

fions of that scale. And as the base AB is reckoned in feet, so must the perpendicular BC be. Hence, the perpendicular is 86 feet; which was required to be found. *Quod erat demonstrandum.*

C A S E II. F I G. 7.

The two acute angles at A and C, and the base AB being given (as in case I.) to find the hypotenuse AC.

Project the triangle ABC, as taught in case I. Then take the hypotenuse AC in your compasses, and applying that extent to the scale C in fig. 4. you will find it to be 114 parts, which are feet if the base AB be taken in feet, or yards if the base AB be taken in yards.

CASE

C A S E III. F I G. 7.

The two acute angles A and B being given, viz. A 49 degrees, and C 41 ; and also the hypotenuse AC 114 feet.
Ques. The number of feet in the base AB ?

The triangle ABC being projected (as shewn in case I.) take the base AB in your compasses, and by measuring it on the same scale (C, fig. 4.) as above, it will be found to contain 75 feet.

C A S E IV. F I G. 7.

The base AB being given, viz. 75 feet, and the perpendicular BC 86 feet.
Ques. The number of feet in the hypotenuse AC ?

Make

Make AB equal to 75 parts of the above scale, and draw BC perpendicular to AB, by Prob. IV. making BC 86 parts of the scale. Then draw the hypotenuse AC, and measure its length by your compasses on the same scale, which length will be found to be 114 parts, which are feet, because AB is reckoned in feet.

C A S E V. F I G. 7.

The base $\overset{\cdot}{A}B$ and perpendicular BC being given (as above) to the two acute angles at A and C.

Construct the triangle as directed in case IV. Then, with the chord of 60 degrees taken in the compasses (see case I.) set one foot in the angular point A, and with the other foot describe the arc ab ; then, without altering

ing

ing the compasses, set one foot in the angular point C, and with the other foot describe the arc *cd*. Lastly, take these arcs at their extremities in your compasses, and by measuring them on the line of chords (see Prob. II.) you will find *ab* (the measure of the angle at A) to be 49 degrees, and *cd* (the measure of the angle at C) to be 41 degrees. Or, having found either of these angles, subtract it from 90 degrees, and the remainder will be the measure of the other.

C A S E VI. F I G. 7.

The base AB and the hypotenuse AC being given, the former being 75 feet, and the latter 114, to find the acute angles A and C.

Make

Make AB equal to 75 parts of the above-mentioned scale, and from the end B draw BC (long enough, be sure) perpendicular to AB. Then, taking 114 parts from the same scale in your compasses, set one foot in the end A of the base AB, and with the other foot cross the perpendicular BC in C, and draw AC. Then measure the angles at A and C, as directed in case V; and you will find that the former contains 49 degrees, and the latter 41.

C A S E VII. F I G. 7.

The base AB and hypotenuse AC being given (as suppose of the above measures) to find the acute angles A and C, and the perpendicular BC.

Project the triangle ABC as directed in case VI. Then measure the angles

A and

A and C, as in that case; and the former will be found to be 49 degrees, and the latter 41. And by taking the length of the perpendicular BC in your compasses, and applying that extent to the scale C (fig. 4.) it will be found to be 86 parts, which are feet, as the base is taken in feet.

HERE ENDETH ALL THE CASES OF
RIGHT ANGLED PLAIN TRIANGLES.

SOLU-

SOLUTION OF THE SEVERAL CASES OF OBLIQUE ANGLED PLAIN TRIANGLES.

In all these cases we shall keep by the same scales of equal parts and chords which were used in the solution of right angled plain triangles.

N. B. In every oblique angled plain triangle (as ABC, fig. 8.) the sum of all the angles make 180 degrees, which is equal to two right angles, or twice 90 degrees.

C A S E I. F I G. 8.

Two sides and an angle opposite to one of them being given, to find the angle opposite to the other side.

In

In the triangle ABC there are given the side AB 104 feet, the side BC 53 feet, and the angle at A 30 degrees.

Ques. The number of degrees in the angle at C?

Take 60 degrees from the line of chords (see Prob. II.) and, with that extent, setting one foot of the compasses in the angular point C, with the other foot describe the arc *efg*; then setting one foot in the extremity *e* of the arc, extend the other foot to the other extremity *g* thereof, and apply that extent to the line of chords. But, as it happens at present, this extent is greater than 90 degrees, which is the whole length of the chord line, and consequently the angle at C is greater than a right angle. Therefore, taking the whole length of the line of chords in your compasses, set that extent from *e* to *f* on the arc *efg*; and then,

then, taking the remaining part *fg* of the arc in your compasses, measure it on the line of chords from the beginning thereof, and it will be found to be ten degrees ; which added to the former 90 makes 100. So that the angle C contains 100 degrees : which was to be found.

C A S E II. F I G. 8.

The three angles and one of the sides being given, to find either of the other sides.

In the triangle ABC there are given the angle at A 30 degrees, the angle at B 50, the angle at C 100 degrees, and the side AC 81 feet (by the scale C in fig. 4.) *Ques.* The number of feet contained in the side AB ?

Take

Take the line AB in your compasses, and measure its length on the scale C in fig. 4, and it will be found to contain 104 of the equal parts of that scale, which are to be esteemed so many feet, because the given side AC is reckoned feet.

C A S E III. F I G. 8.

Two sides and an angle opposite to one of them being given, to find the other side.

In the triangle ABC there are given, the side AB 104 feet, the side AC 81 feet, and the angle at 30 degrees. *Ques.* The length of the side BC in feet?

Take BC in your compasses, and measure its length on the aforesaid scale, and you will find it to be 53 parts or feet: which was required.

C A S E

C A S E IV. F I G. 8.

Two sides and the angle included between them being given, to find the other angles.

In the triangle ABC there are given, the side AC 81 feet, the side BC 53 feet, and the included angle at C 100 degrees. *Ques.* The angles at A and B?

Measure these angles as shewn in prob. II. and you will find the angle A to be 30 degrees and the angle B 50 : which was to be done.

C A S E V. F I G. 8.

Two sides and their included angle being given, to find the third side.

In

In the triangle ABC the same things are given as in case IV. And it is required to find the third side BC.

Take BC in your compasses, and measure it on the same scale as you have hitherto used for this triangle, and you will find it to be 53 feet.

C A S E VI. F I G. 8.

The three sides being given, to find the three angles.

In the triangle ABC are given, the side AB 104 feet, the side AC 81 feet, and the side BC 53. | *Ques.* The number of degrees in each of the angles AB and C ?

Measure the angles as taught in Prob. II. (answering to fig. 3.) and you will find the angle at A (fig. 8.)

to

[70]

to be 30 degrees, the angle at B 50,
and the angle at C 100: which was
to be done.

HERE ENDETH ALL THE CASES OF OB-
LIQUE ANGLED PLAIN TRIANGLES.

We shall next describe the quadrant,
and then shew the method of finding
inaccessibile heights and distances ; in
which, some of the foregoing cases
will be found useful.

PRO-

P R O B L E M V.

A Q U A D R A N T.

F I G U R E 9, 10.

This is a fourth part of a circular plate, divided into 90 equal parts or degrees, which is a fourth part of the number contained in a circle. A thread Cd hangs from its centre C ; and the end d of the thread is fixt to a little weight D , called the plummet. The thread is called the plumb-line, and the general use of the quadrant, thus fitted up, is to take the angular height of objects above the level of the center C of the quadrant, or their depression below it.

Let GCE (fig. 9.) be an horizontal line, and EF an upright object.

It

It is plain, that if a man puts his eye to the corner A of the quadrant, and holds its face perpendicular to the horizon, so that the plumb-line may hang freely and perpendicularly on the face of the quadrant, and hold the quadrant so as that looking along the side AC he may just see the top of the object at F, the plumb-line will shew the angle of the object's height above the horizon, which will be equal to the number of degrees counted from B in the arc Bd. For, just as many degrees as the corner A of the quadrant is depressed below the horizontal line GCE in the arc GA, so many degrees will the side CB of the quadrant deviate from the perpendicular Cd. And since ACfF and GCeE are strait lines, the angle fCe must be equal to the opposite angle GCA; and therefore the arc ef must contain the same number

number of degrees as AG does ; which is equal to the number of degrees in the arc Bd of the quadrant, namely 20. So that the angle of the height of the object EF above the level of the center C of the quadrant is 20 degrees.

The depression of any part of a visible object below the level of the observer's eye may be easily found by the quadrant, thus. If the observer be on the top or side of a hill (fig. 10.) as at C, and sees an upright object as EF at the foot of the hill, and wants to know the angle of its depression below the line CbD which is on a level with his eye at C. Let him hold the quadrant so, as that by looking along the edge CB, he may just see the foot of the object at F, if he wants the depression of the foot ; and the plumb line hanging freely on the face of the quadrant will shew the angle of depression,

E

pression, by the number of degrees it hangs upon, counted from A in the arc *Ad* (which is here represented to be 29 1-half) for the arc of depression is *bB*, which is equal to the arc *Ad*; as is plain to sight by the figure. The quadrant has generally two thin brass plates with holes in them (called the sights) to look through at the object. And a line drawn through these holes is parallel to the straight edge of the quadrant.

P R O B L E M VI.

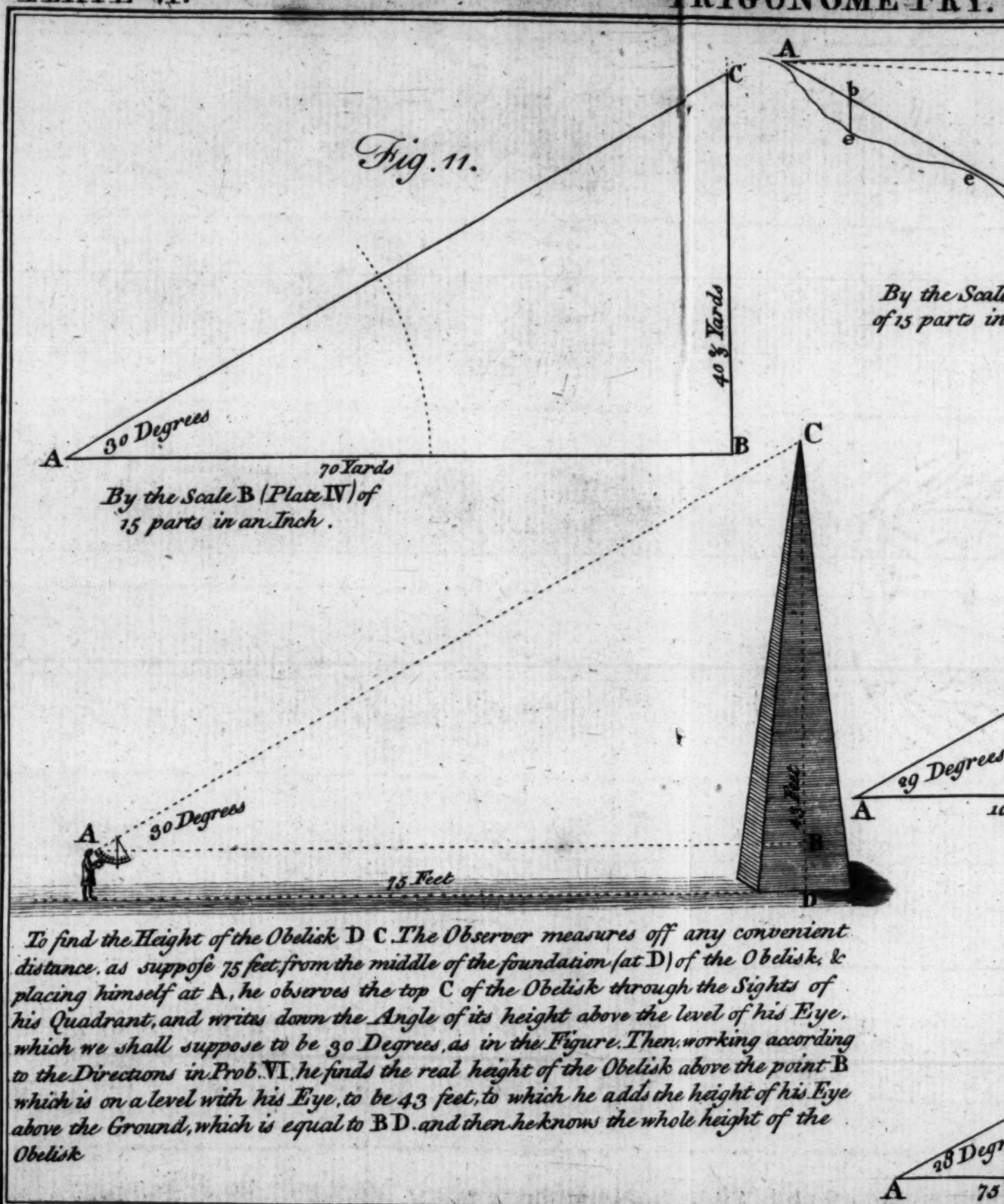
To find the height of a house or tower, provided it stands on level ground.
Fig. 11.

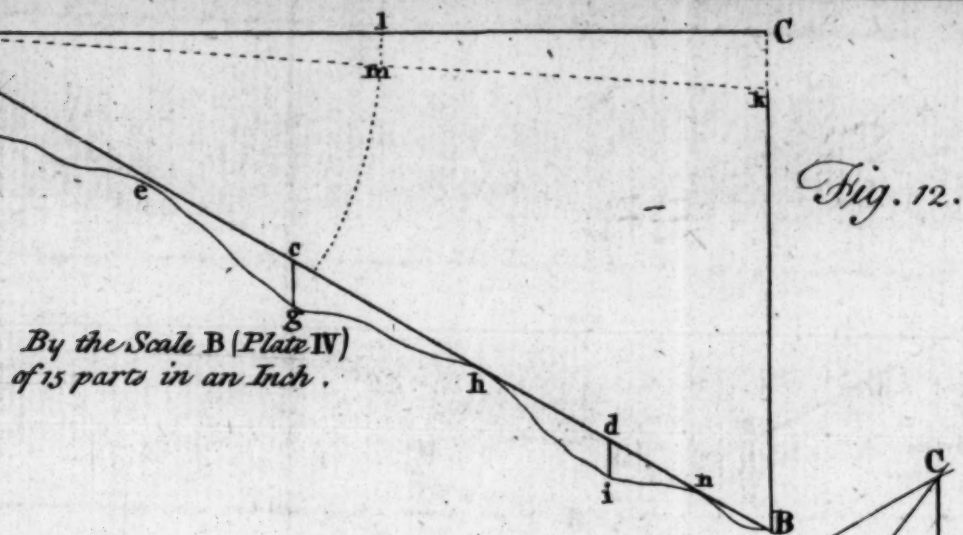
Retire to some convenient distance from the tower, on level ground, as suppose

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*By the Scale B (Plate IV)
of 15 parts in an Inch.*

*By the Scale F (Plate IV) of
35 parts in an Inch*

Fig. 13.

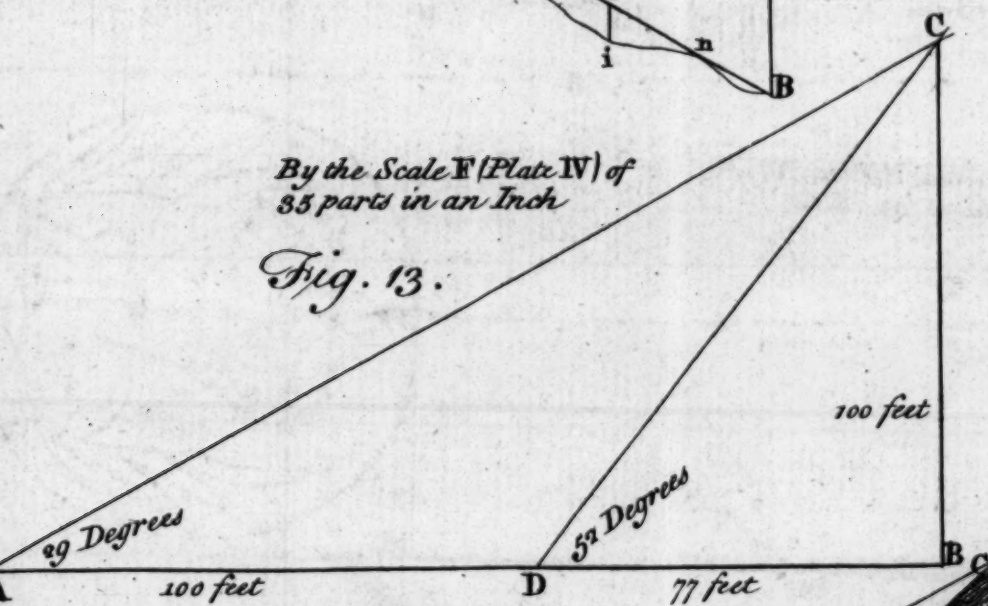
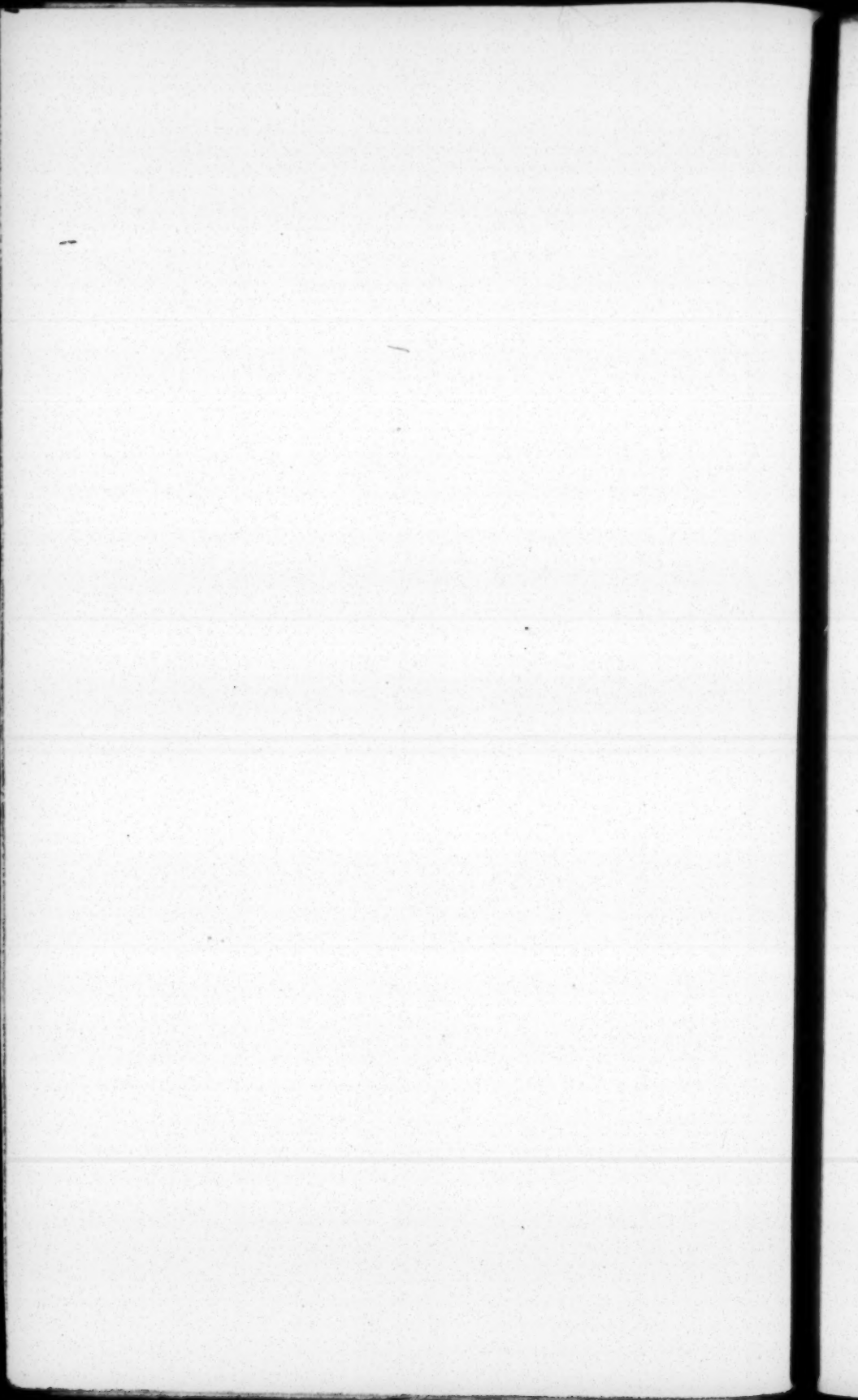


Fig. 14.

*By the Scale F (Plate IV) of
35 parts in an Inch.*





pose seventy yards, and standing there, observe the top of the tower through the sights (or along the edge) of the quadrant, and *take the angle of its height*, as suppose thirty degrees, above the level of your eye, as directed in the last problem (page 73.) Then go home, and project the triangle ABC, (fig. 11.) as follows: the larger the better.

Suppose the given distance AB from the tower to be seventy yards, and the angle A of the height of the tower to be thirty degrees. *Ques.* The height of the tower BC in yards?

From either of the scales of equal parts, B, C, or D, (fig. 4. page 50.) as suppose from the scale B, take seventy parts in your compasses, and make the line of distance AB equal thereto. Then draw the line AC, making an angle of thirty degrees with

the line AB, and raise the line BC (for the tower) perpendicular to AB, drawing it on from B till it meets the line AC. Lastly, take the length of the line BC in your compasses, and measure it on the same scale from which you laid down the line AB, and you will find it to be forty parts and about two-thirds of the forty-first part, which is to be esteemed so many yards, since the distance was taken in yards. So that the height of the tower, above the level of the observer's eye, is forty yards and 2-thirds; to which add the height of the observer's eye above the ground, and the whole will be the height of the tower BC.

When larger distances are taken, some of the smaller scales, as C, D, or E, &c. must be used, that the figure may come within the compass of the paper.

This

This problem answers to case I. of right angled plain triangles, page 47.

P R O B L E M VII.

To take the height of a tower standing at the foot of a hill, where no level ground can be had to observe it by.

In fig. 12, let AB be part of the side of a hill, and Bk a tower standing at the foot of the hill; the height of which tower is wanted to be known in yards.

Measure any convenient distance, as suppose eighty yards, from B to A, up the side of the hill; which may be easily done if the slope is even, as *AbcdB*. But if it has hollows in it, as at *e, g, i*, posts must be set up in

E 3

them,

them, so that their tops may be in a straight line with the little risings between them, and the straight distances *nd*, *db*, *bc*, &c. measured all the way from B to A.

Standing at A, take the angle of depression (by Prob. V. page 73.) of B, the foot of the tower, by means of the quadrant, and also the angle of depression of the top of the tower at *k*, both below the horizontal line AC: and write them down. Now let us suppose that the angle BAC of depression of the foot of the tower at B was twenty-nine degrees 1-half, and the angle of depression CA*k*, of the top of the tower was three degrees 1-quarter; which being subtracted from twenty-nine and an half, leaves twenty-six degrees 1-quarter for the angle of the tower's height.

Draw

Draw the straight lines AB and AC , making an angle of twenty-nine degrees 1-half (Prob. I. page 47.) Then, from any convenient scale of equal parts (as the scale B , page 50.) take off eighty equal parts for the yards of the observer's distance from the foot of the tower, and set them off with your compasses from A to B , and draw BkC perpendicular to AC . This done, take twenty-six degrees 1-quarter from the line of chords, with your compasses, and set them off from c to m , in the arc cml which measures the angle CAB : and, from A draw the straight line Amk through the point m ; and it will cut the upright line BC in the point k : so that the line Bk will represent the height of the tower. Lastly, take Bk in your compasses, and measure its length on the same scale of equal parts by which you set off

the eighty yards of distance from A to B; and you will find the height of the tower Bk to be thirty-six yards.

PROBLEM VIII.

To find the height of a tower as BC when the distance from it cannot be measured, on account of an intervening river as BD; and also to find the breadth of the river, Fig. 13.

On the farther side of the river, (at D) from the tower, take the angular height of the tower, by the quadrant, which angular height we shall suppose to be fifty-two degrees.

Then, from D (the side of the river BD) measure off any convenient number of feet, as suppose one hundred, to A: and standing at A, take
again

again the angular height of the tower ; which we shall suppose to be twenty-nine degrees : and your work in the fields is done

Draw the strait line ADB ; and from any of the smaller scales (as from the scale F, page 50, of thirty-five parts in an inch) set one hundred parts which you are to reckon so many feet. Then from A draw the strait line AC, making an angle of twenty-nine degrees with the line ADB ; and from D draw the line DC, making an angle of fifty-two degrees with DB ; and the two observed angles of altitude will be projected.

Now, as it is plain, that the top of the tower at C must be the point C where the lines AC and DC intersect each other ; therefore, from the point C let fall the perpendicular CB on the line ADB : and taking CB in

your compasses, measure its length on the scale F (page 50.) and you will find it to be one hundred parts, which are to be reckoned so many feet for the height of the tower above the level of the observer's eye.

Lastly, take DB (the breadth of the river) in your compasses, and by measuring it on the same scale, you will find it to be seventy-seven feet.

The following problem for finding the perpendicular height of a hill, and also for finding the breadth of that part of the base which is between the perpendicular and the observer, is exactly of the same nature with this problem.

PROBLEM

P R O B L E M IX.

To find the perpendicular height of a hill, Fig. 14.

Let E be a hill whose perpendicular height BC is to be found.

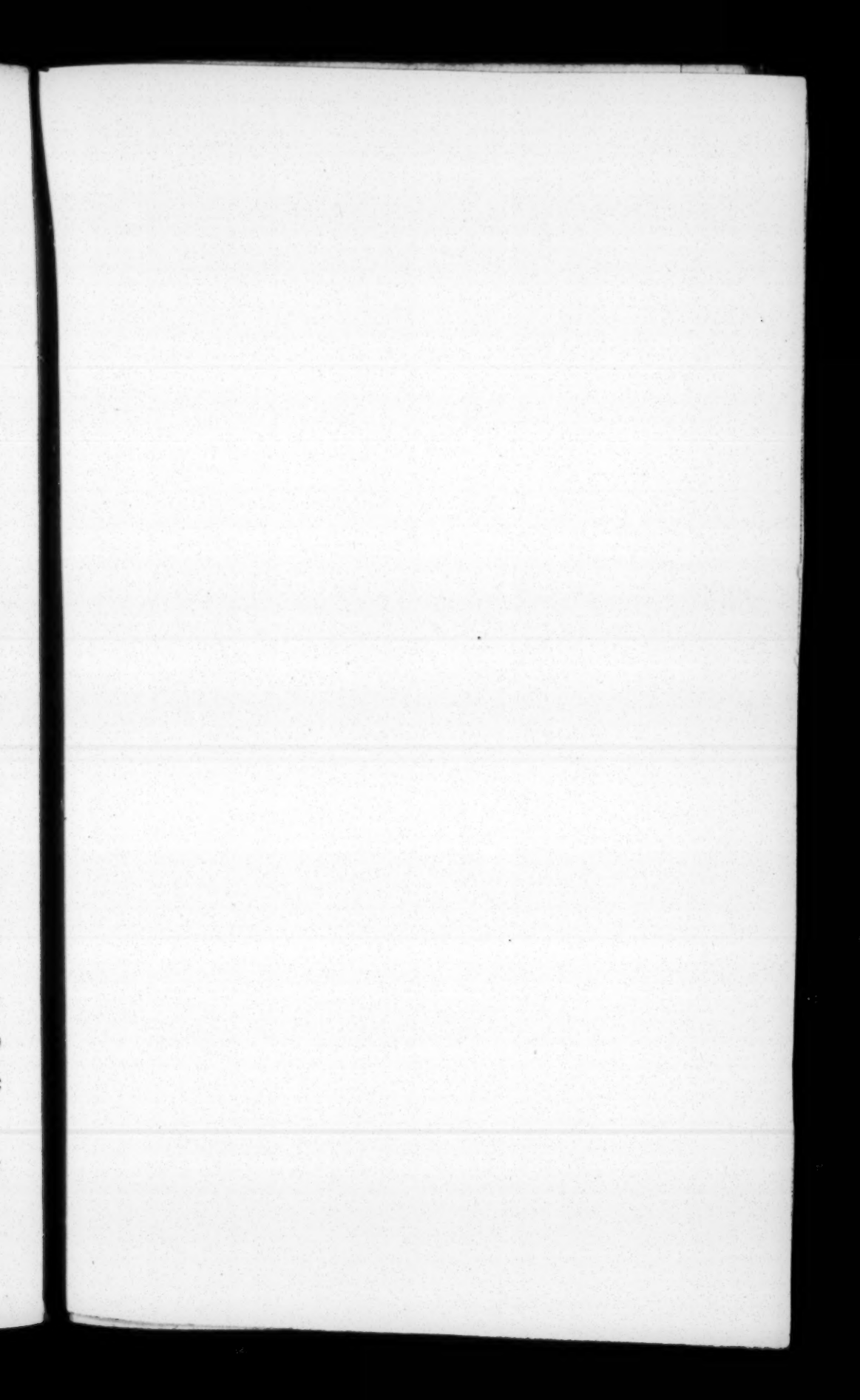
Place yourself as near to the foot of the hill (suppose at D) as you can, see its top; and standing at D, take the angular height of the hill by your quadrant, which we shall suppose to be forty-two degrees and an half.

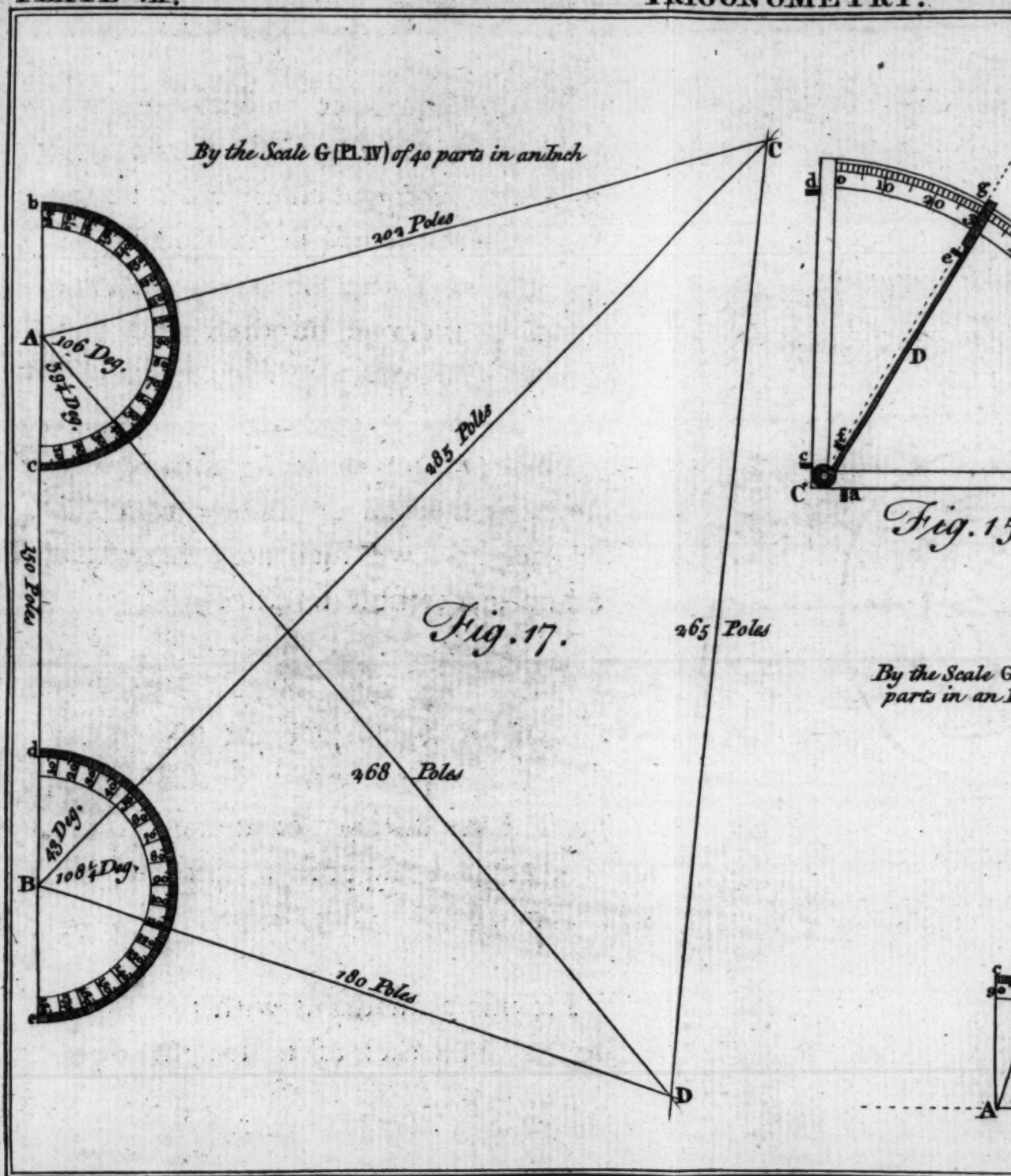
Then measure off any convenient distance, as seventy-five yards, towards A; and standing at A, observe again the angular height of the hill, which we shall suppose to be twenty-eight degrees; and your work in the field is done.

Draw

Draw the strait line ADB, and taking seventy-five parts from some of the fore-mentioned scales, as suppose from the scale F, set these parts with your compasses from A to D. Then draw the strait line AC, making an angle of twenty-eight degrees with ADB; and draw the straight line DC, making an angle of forty-two degrees and an half with DB. And thus, having projected the two observed angles, the top of the hill must be at the intersection C of the line AC and DC. Therefore, from the point C draw CB perpendicular to DB; and taking CB in your compasses, measure its length on the same scale from which you set off the seventy-five parts from A to D, and you will find it to contain one hundred parts, which are to be esteemed so many yards for the perpendicular height of the hill.

By





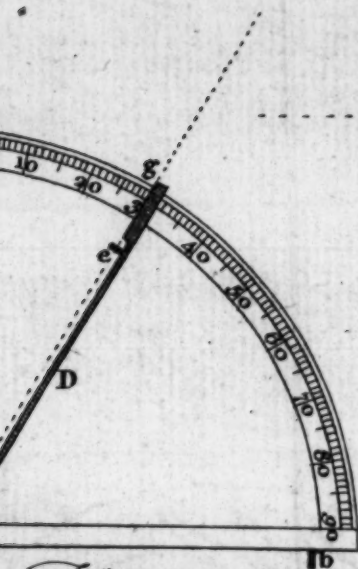


Fig. 15.

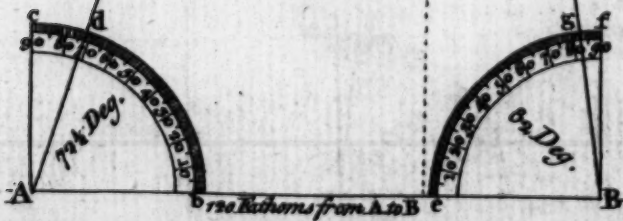
By the Scale G (Pl. IV) of 40 parts in an Inch

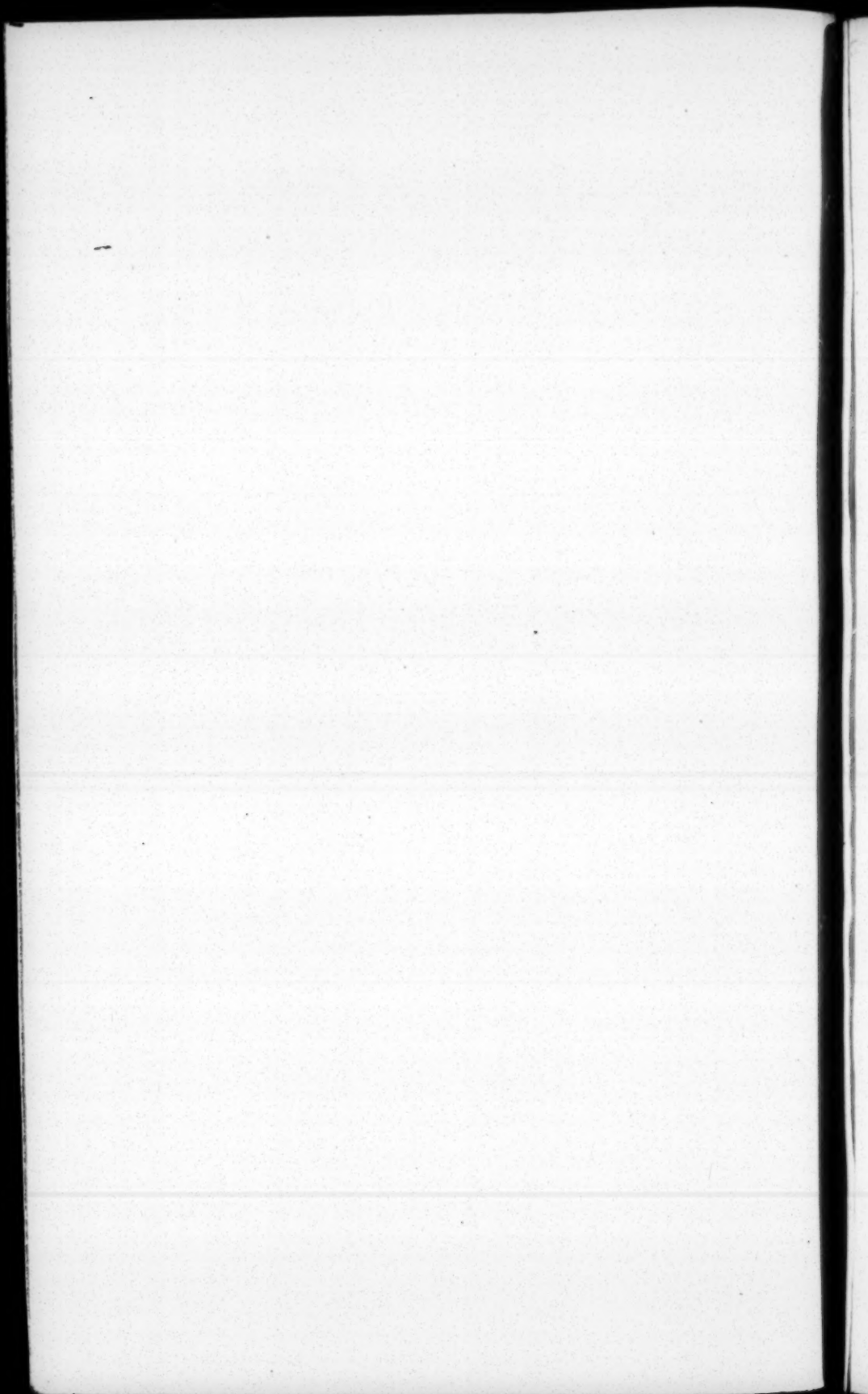
276 Fathoms

264 Fathoms

266 Fathoms

Fig. 16.





By the same kind of measurement, the part *Be* of the base of the hill, from the perpendicular *BC*, to the place where the hill begins to rise, on the side next the observer, will be found to be one hundred and two yards.

These examples being sufficient to shew the method of finding inaccessible heights, we shall next shew how to find inaccessible distances.

P R O B L E M . X.

To find the distance of an inaccessible object, as suppose a ship at sea, Fig. 16.

Provide a quadrant with two sights (fig. 15.) on each of its straight edges,
as

as *a*, *b*, and *c*, *d*; and also with a moveable index as *CD*, turning on the center *C*, and having two sights as *e* and *f*, whose holes for looking through are in a straight line with the center *C* and the fiducial edge *g* which marks the degrees in the quadrant.

In fig. 16, at any convenient place as *A* on the shore, lay the quadrant flat on a table, and from *A* measure off a convenient distance, along the shore, as suppose one hundred and twenty fathoms, to *B*, and set up a mark at *B*. Then direct the edge *Ab* of the quadrant toward the mark at *B*, so as you may see the mark through the sight-holes; this done, keep the quadrant steady, and move the index *Ad* till you see the ship at *C* through the sight-holes of the index, and write down the number of degrees cut by
the

the index on the quadrant, reckoning from *b* to *d*; which we shall suppose to be seventy-one degrees and an half.

Then remove the quadrant to *B*, having left a mark where it stood at *A*; and placing it flat on the table, set it so as you may see the mark at *A* through the sight-holes on the side *Be*. This done, move the index till you see the ship at *C* through the sight-holes of the index, and write down the number of degrees cut by the index in the quadrant reckoning from *e* to *g*, which number we shall suppose to be eighty-two. And you have done the part of your work without doors.

Draw the straight line *AB* for part of the shore, and taking one hundred and twenty parts, for so many fathoms, from the scale *G*, set them with your compasses from *A* to *B*. Then, from *A*, draw the straight line *AC*, making
an

an angle of seventy-two degrees and an half with the line AB; and from B, draw the straight line BC; making an angle of eighty-two degrees with the line BA. This done, take the lines AC and BC separately in your compasses, and measure them on the scale G: the former will be found to be two hundred and seventy-six parts, for the number of fathoms that the ship is distant from A; and the latter will be found to be two hundred and sixty-six fathoms for the distance of the ship from B. The ship being supposed to be lying at anchor. Lastly draw Ce perpendicular to AB, and its length measured by the compasses on the scale, will be found to be two hundred and sixty-four fathoms and an half from that point of the shore to which she is nearest.

In

In the same manner may the breadth of a river be found, by using C as a mark or object on the farther bank of the river.

If your scale be too short, set its whole length as from A to *b*, and then measure the remaining part *bC*.

P R O B L E M XI.

To find the distances of two inaccessible objects as C and D (fig. 17.) from two given points as A and B, and likewise the distance of these objects from one another.

For this purpose, instead of a quadrant (as in the last problem) you must have a semi-circle, divided into one hundred and eighty degrees, with a moveable

moveable index, and sights, as in the quadrant.

Pitch on two places, as A and B, from each of which you may see the inaccessible objects C and D, and measure the distance from A to B, which we shall suppose to be one hundred and fifty poles *.

Place the semi-circle on a table at A, in such a manner as that looking through the sights on its edge *bc* you may see a mark set up at B. Then move the index till through the sights on it you can see the inaccessible object D, and write down the number of degrees cut by the index, reckoned from *c*; which number we shall suppose to be thirty-nine 1-quarter. Then move on the index till through its sights you perceive the other inaccessi-

* A pole or perch is five yards and an half, which makes sixteen feet and an half.

ble object C, and write down the number of degrees cut by the index from *c*, which we shall suppose to be one hundred and six.

Set up a mark at A, and remove the semi-circle to B, and placing it there on the table, set it so as you can perceive the mark at A through the sights on the edge *de*; and then, moving the index till you can first see the inaccessible object C through the sights of the index, and then till you can see the other object D through them; write down the number of degrees cut by the index at both these times, counting from *d*; as suppose forty-three degrees for C, and an hundred and eight 1-quarter for D, and your work in the field is done.

From either of the small scales (as from G, page 50.) take an hundred and fifty parts, for so many poles, and
set

set them with your compasses from A to B, and draw the line AB. . Then draw AD making an angle of thirty-nine degrees 1-quarter with AB, and draw AC making an angle of one hundred and six degrees with AB. Draw also BC making an angle of forty-three degrees with BA and BD making an angle of one hundred and eight degrees 1-quarter with BA.

The intersections of these lines at C and D are the places of the above-mentioned inaccessible objects, whose distances from each other, and from the places of observation at A and B, are found by measuring the lines CD, AC, AD, BC, BD, on the scale G with the compasses; which distances will be found, from C to D two hundred and sixty-five poles, from A to C two hundred and two, from

from A to D two hundred and sixty-eight, from B to C two hundred and eighty-five, and from B to D one hundred and eighty, as in the figure.

PART

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From A to B two hundred and fifty
feet; from B to C two hundred and
fifty feet; and from C to D one
hundred and eighty feet in the

P. A. B. C.

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PART THE THIRD.

OF

O P T I C S,

OR,

THE CONSIDERATION OF THE
HUMAN EYE AND THE NA-
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THE distance of the earth from the sun is upwards of 81 millions of miles ; and it is demonstrable that light comes from the sun to the earth in 8 minutes. Hence, the velocity of light is so great, that it moves upwards of 10 millions of miles in a minute of time.

A cannon ball could not move from the earth to the sun in less than 20 years. So that, light travels as far in 8 minutes as a cannon ball could travel in 20 years.

But there are 10,512,000 minutes in 20 years. And this number being

ing divided by 8 minutes, quotes 1,314,000, for the number of times that light moves swifter than a cannon ball.

Now, suppose we say (for the sake of round numbers) that light moves only one million of times as swift as a cannon ball moves; it is plain, that if a million of particles of light put together were as big as a single grain of sand, we could no more open our eyes to receive the impulse of light, than we durst to have sand shot point blank against them from a cannon.

When any object is illuminated, either by the sun or a candle, every illuminated point of the object reflects the light in all manner of directions. And it is by this reflection of the light that objects become visible.

Thus, suppose the object ABC (fig. 1.) to be illuminated by the sun on the

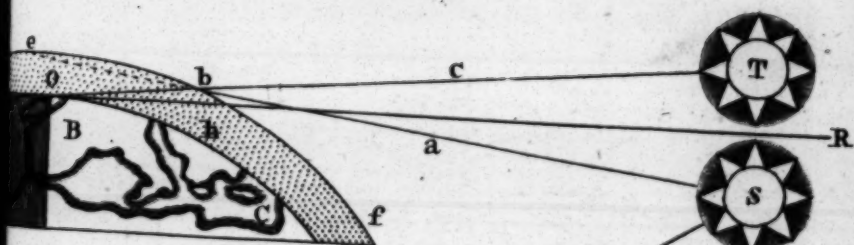
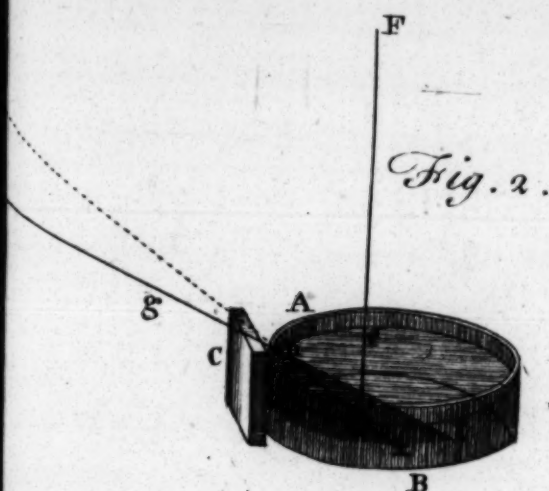
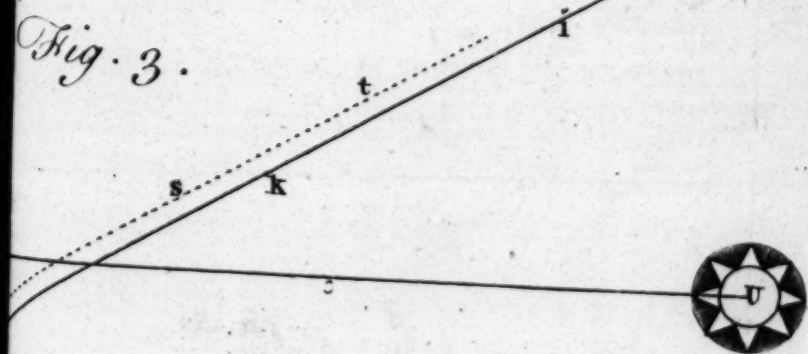


Fig. 3.



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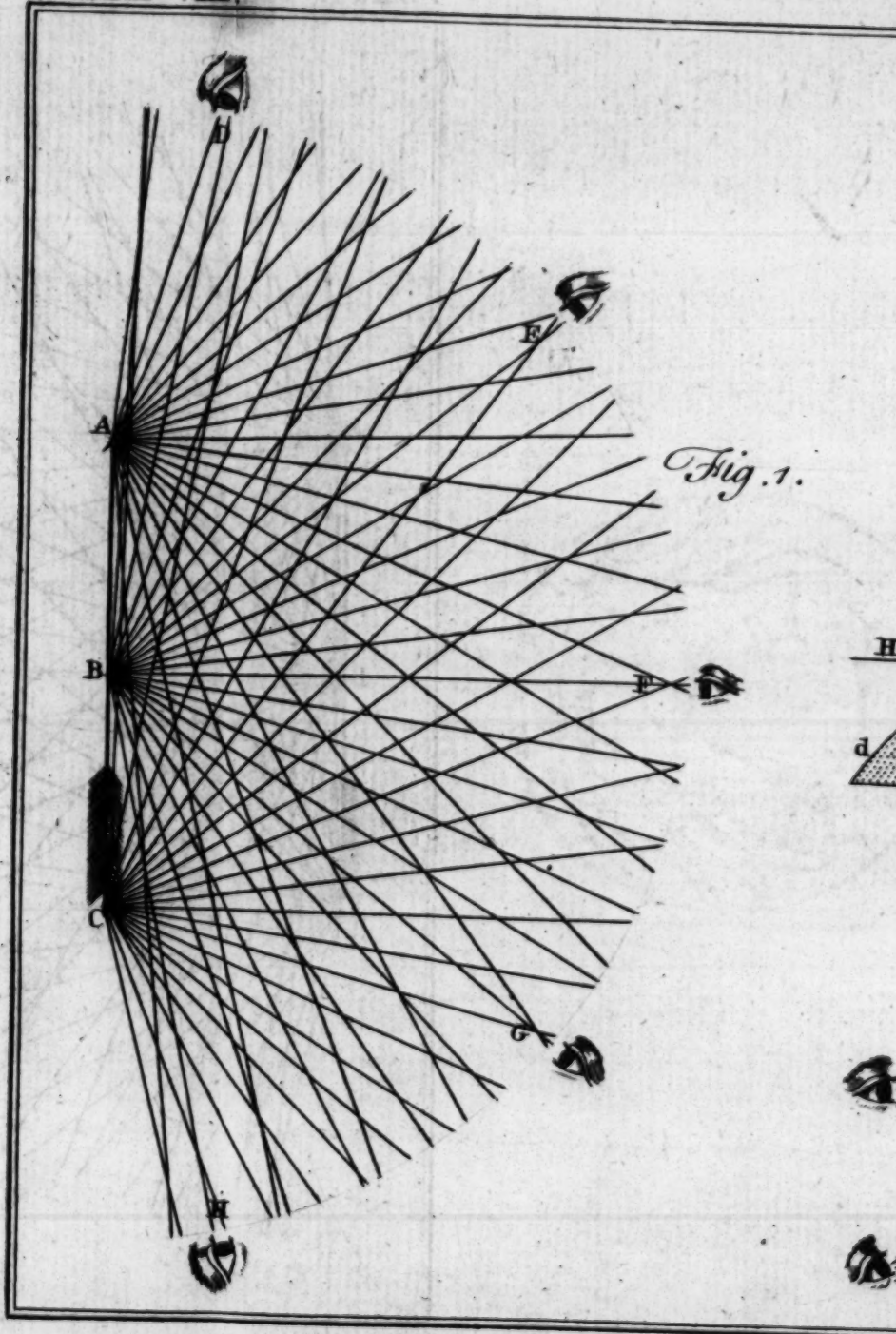
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PLATE VIII.



OPTICS.

To face page 98.

Fig. 1.

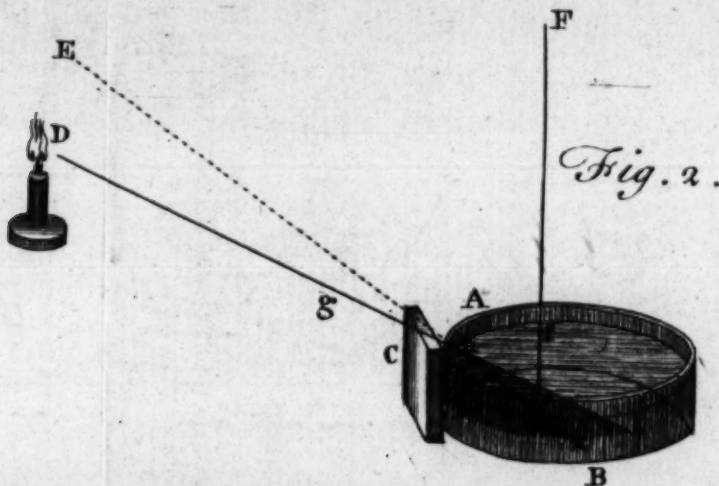


Fig. 2.

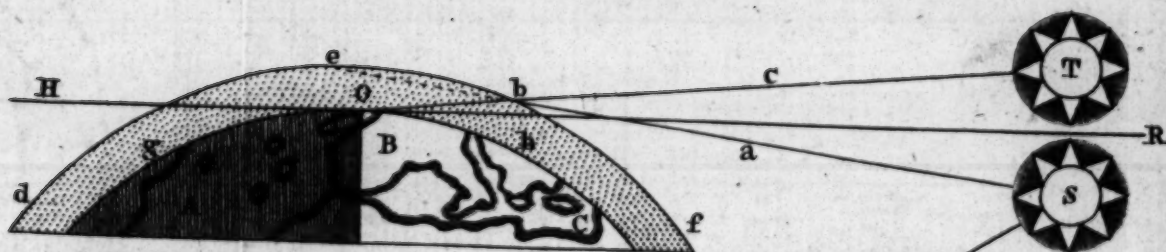
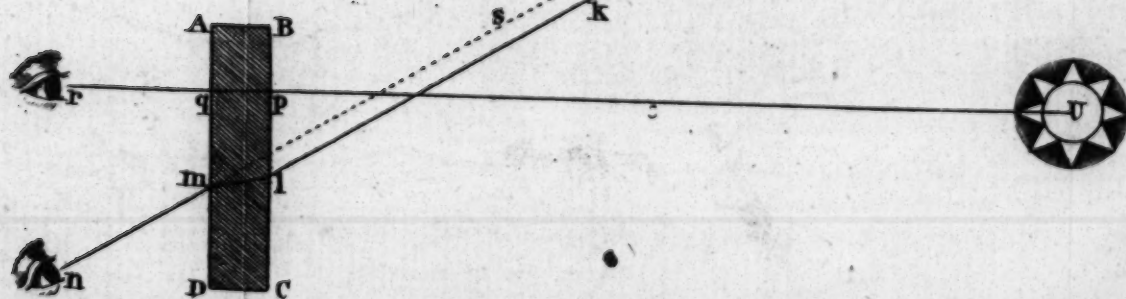
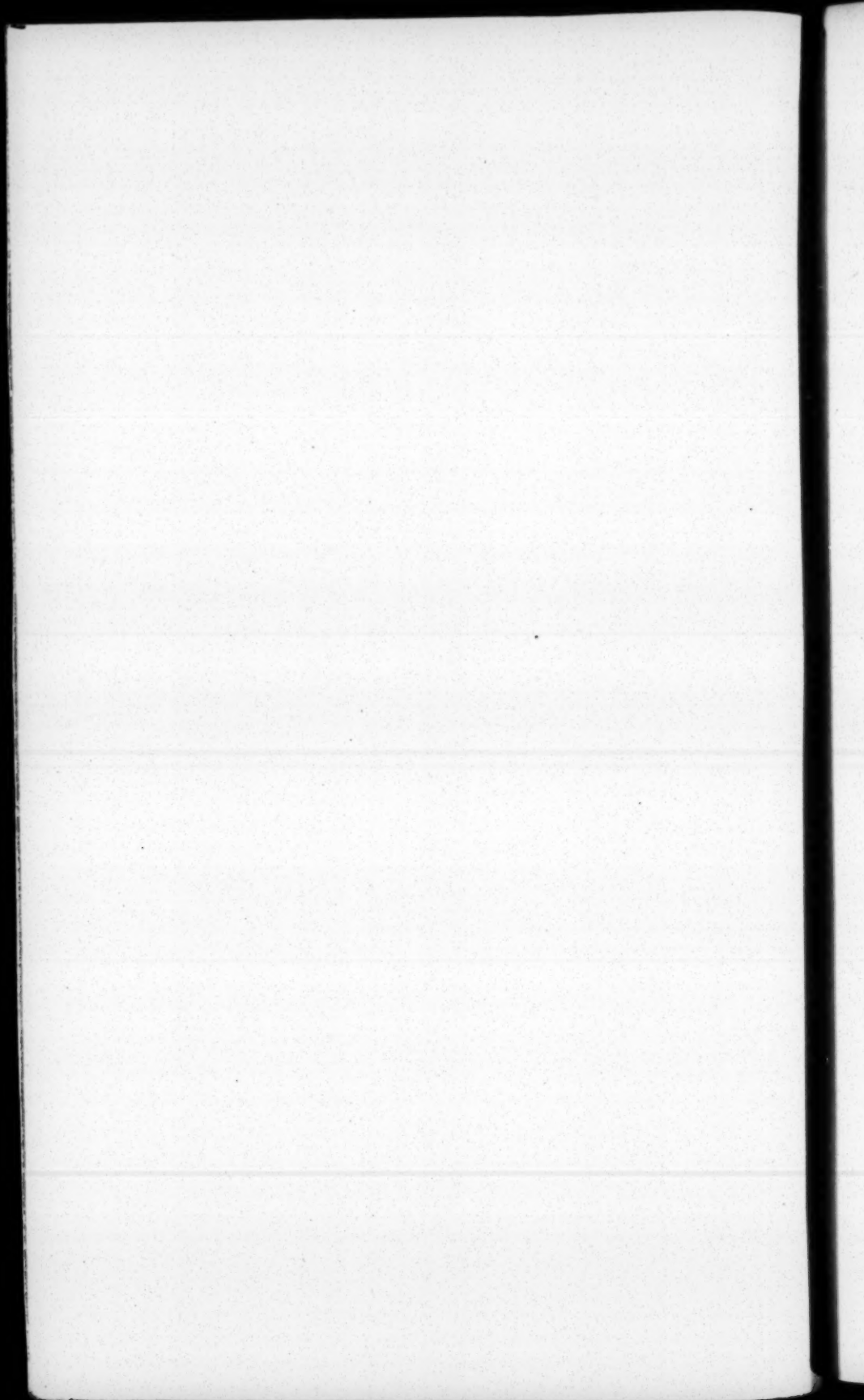


Fig. 3.



J. Mynde fecit.



the right-hand side, the points A, B, and C, reflect the rays of light every way through the hemisphere DEFG; and therefore, these three points will be visible to an eye placed any where in that hemisphere. But all the intermediate points of the object reflect the light in the same manner: and therefore the whole object will be visible to an eye placed any where on the enlightened side.

The left-hand side, on which the sun shines not, would be altogether invisible, if it were not for the rays of light reflected upon it from the terrestrial objects on that side. But as the left side is much dimmer than the right, we see how much stronger the direct light of the sun is than the reflection of light from rough and unpolished objects. Every object would

be dark, and consequently invisible, if it reflected none of the light.

CONCERNING THE REFRACTION- GIBILITY OF LIGHT.

The rays of light proceeding from a luminous body go on in straight lines, whilst they continue in any medium of an equal and uniform density or compactness. But when they pass out of one medium obliquely into another, they are refracted or bent out of their rectilineal course at their entrance into the different medium. Let AB (fig. 2.) be a glass cup, and C a board set up between the cup and a candle at D. The shadow *bilk* of the board will fall into the cup, and if there be no water in it, the shadow will reach to *i*. So that if a thread be stretched from *i*, straight over the top of
of

of the board, and continued to the candle, it will come into the flame thereof; which shews, that the ray *Dghi* goes on from the candle in a straight line. Moreover, if a person places his eye below the bottom of the cup, at *i*, and looks over the top of the board *C*, he will see the flame of the candle even with the top of the board.

Now let water be poured into the cup, so as to fill it up almost to the brim, and you will perceive the shadow move from *i* to *k*; which shews that the ray *Dghi* is bent from its rectilineal course, into the form *Dghk*, and that the bended part is at the surface of the water at *b*. So that, if a person now places his eye under the glass bottom at *k*, he will see the candle *D* just over the board; and the candle will seem to him to be raised from *D* to *E*, because it will appear

to him to be in the right line kbE , in direction of the bended part bk of the now refracted ray.

When a ray of light falls perpendicularly on the surface of water, or any other medium, the ray goes on in the same perpendicular direction. Thus, the ray Ffm , falling perpendicularly on the surface of the water at f , goes on in the same direction fm , without suffering any refraction at all. Which shews, that the rays of light must enter obliquely into a medium, if they are refracted by it.

The rays of light come straight from the sun, in the open space, till they fall upon the earth's atmosphere, and then they are refracted by the denser medium of the atmosphere, so as to bring the sun in view every day, before he rises in our horizon ; and to keep him in view for some time after he is really set below it.

And

And by means of this refraction, we have about a whole summer's more sunshine in 100 years than we would have if there were no atmosphere.

Let ABC (fig.3.) be a portion of the earth, whose convex surface is gOb , and let $debt$ be the top of the atmosphere. Let also HOR be the horizon of an observer on the earth's surface at O, and let S be the sun, below the horizon. A ray of light Sab comes all the way strait from the sun till it falls obliquely on the top of the atmosphere, as at b , where it is turned out of its rectilineal course : and so, instead of going on in the same direction be , it goes in the direction bo , to the observer's place at O, and therefore, to this observer, the sun, even before he rises in the horizon HOR, will appear above the horizon at T; because he will be seen in the direction of Ob , the re-

fracted part of the ray $ObaS$: and Ob produced strait outwards, will be in the rectilineal direction $ObcT$.

If a ray of light $Sikl$ falls obliquely upon the surface of a plane glass $ABCD$ at l (see the lower part of fig. 3.) the ray will not pass through the glass in direction ikl , but will be refracted in the direction lm in the glass: and if the glass be equally thick, that is, if the side AD be parallel to the side (or surface) BC , the ray leaving the glass at m will be refracted the contrary way, and go on in the direction of mn , parallel to the direction ikl in which it came to the glass. And, an eye at n will see the sun S , not in his true place at S , but higher, in direction of the line $mnst$. If a ray op falls perpendicularly on the surface of the glass, as at p , it will suffer no refraction in passing through the glass, but will go
on

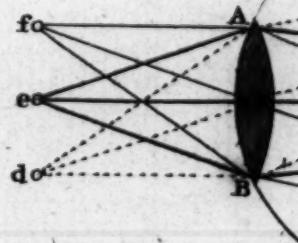
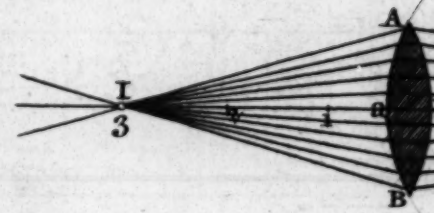
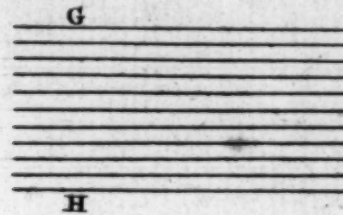
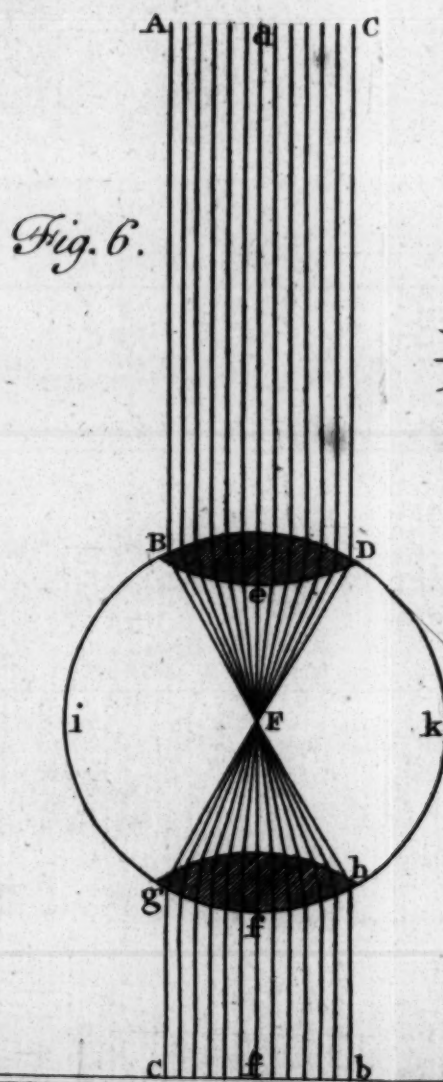
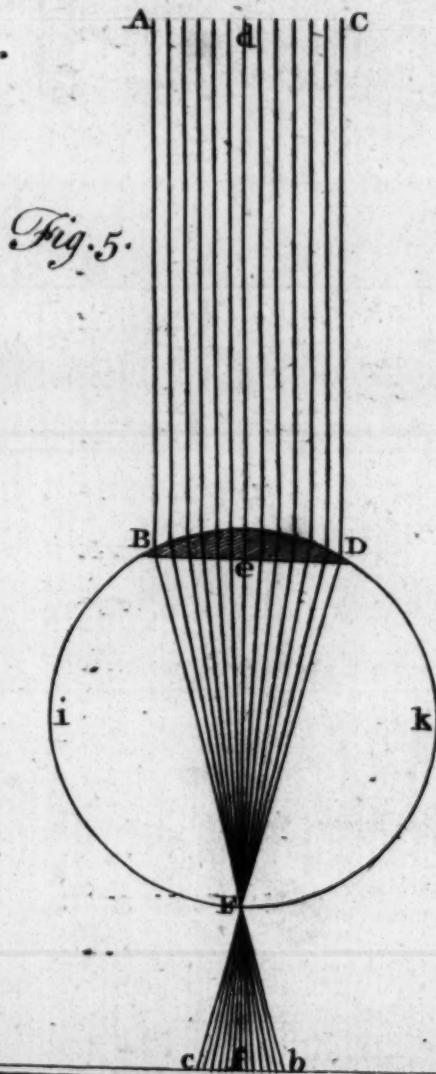


Fig. 7.

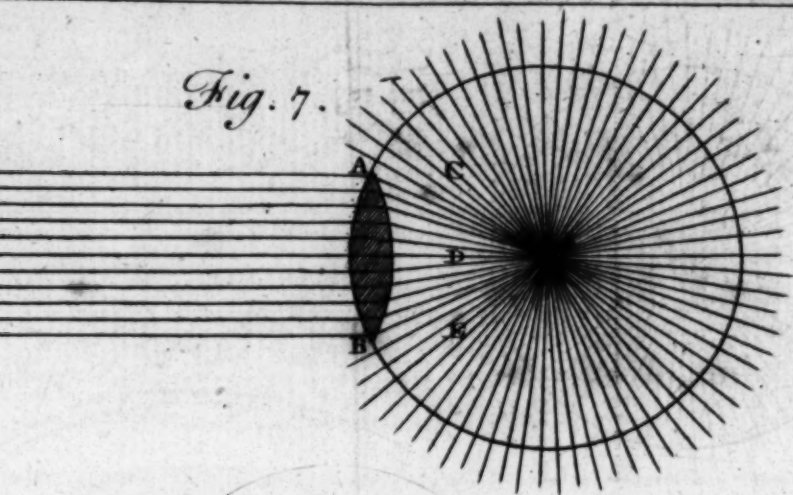


Fig. 8.

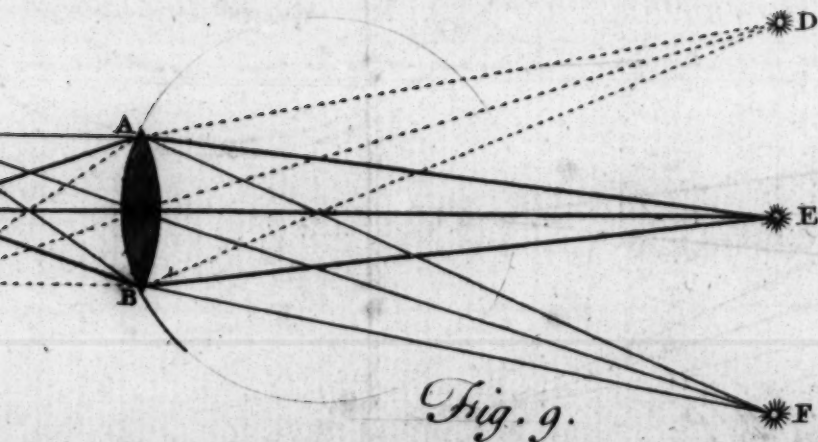
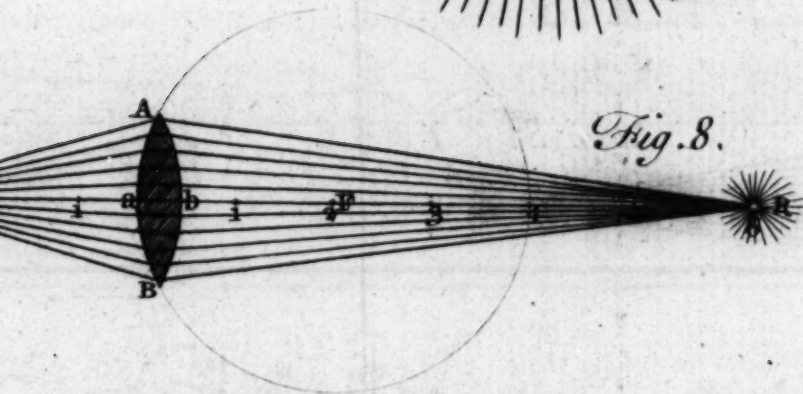
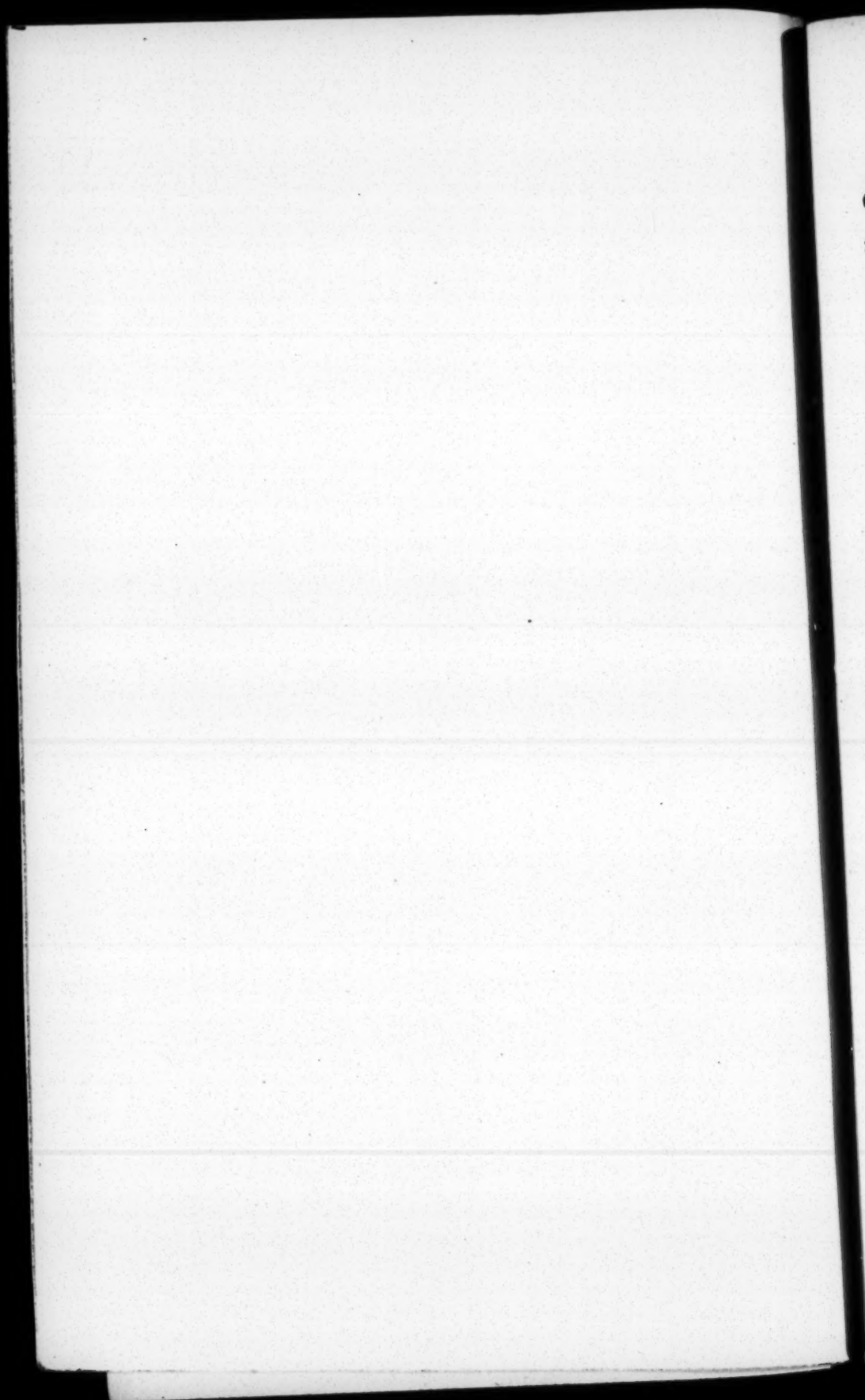


Fig. 9.



on in the strait line *pqr* continued ; and an eye at *r* will see the sun in his true place at *U*.

Fig. 4. shews five sorts of ground glasses edgewise. *A*, is called a plano-convex glass, because it is plane on one side and convex on the other. *B* is called a double convex glass, because it is convex on both sides. *C* is called a plano-concave glass, because it is plane on one side and concave on the other. *D* is a double-concave glass, being concave on both sides. And *E* is called a meniscus glass, which is concave on both sides ; but more so on one side than the other. All these sorts of glasses are called lenses, and the right line *FG* is their axis.

The suns rays may be reckoned parallel at the earth, as *ABCD* (fig. 5, 6.) at the earth's surface, on account

of the sun's vast distance from the earth.

If parallel rays, $ABCD$ (fig. 5.) fall on a plano-convex glass BDe , so as the middle ray def be perpendicular to the plane surface of the glass, they will be so refracted in passing through the glass, that they will meet in a point F , in the further side of a circle $BDkFiB$, of which the convex side of the glass BC is a part of a sphere or globe whose diameter is equal to the diameter of the circle. The point F where the rays meet, is called the principal focus of the glass; and, if the rays are not stopt at the focus, but are suffered to pass on, they will diverge from the focus toward the contrary sides. Thus, the ray CDF will go on from the focus in the direction Fc , and the ray ABF will go on from the focus in the direction Fb .

The

The middle ray *def* is not refracted at all, because it falls perpendicularly on the glass. Whatever side of the glass is turned toward the sun, the distance of the focus *F* will be the same from the plane side *e* of the glass.

If parallel rays, *ABCD* (fig. 6.) fall upon a double convex glass *BDe*, they will be so refracted as to meet and cross one another in a point *F*, which is the center of a circle *BDkfiB*, equal to the diameter of a sphere, of which either of the convex sides *BD* or *BeD* is a portion. And the rays, after crossing, will diverge to the contrary sides, in the space *Fgb*, just as much as they converged in the space *BFD*; and would continue to go on in this diverging state. But if such another double-convex glass, *gfb* be placed in the side of the circle opposite to *BeD*, the rays, after passing through

through the glass gfb will go on parallel to one another, in the space $ghbc$, continued in the same manner as they came parallel to one another in the space $ACBD$, to the glass BeD . But, because they cross in the focus F , they change sides afterward. Thus, the parcel of rays $ABdeF$, which are on the left side of the middle ray deF , after meeting at F , cross over to the right side of the middle ray, and go on in the space $FbbfF$. And the rays $dCDeF$ cross the middle ray at F , and then go on in the space $FgcfF$. So that, $ABFbb$ is one of the outside rays, and $CDFgc$ is another.

A raidant point of any object is a point from which rays of light proceed, as F , in fig. 7. And these rays CDE continually diverge in straight lines every way from that point.

If

If the radiant point be in the focus F of a convex glass AB , all the rays that fall upon the glass will be refracted in passing through it, and after leaving it they will go on in parallel lines in the space $GABH$.

If the radiant point R (fig. 8.) be further from the convex glass than its focus F , the diverging rays RA , RB , &c. which fall upon the glass AB , will converge after passing through the glass, in the space $ABIA$; and will all meet in a point I , where they will form the image of the radiant point R .

If the focal distance aF is known, and also the distance aR of the radiant point, from the glass AB ; the distance of the image I , of the radiant from the other side of the glass, may be found by this rule: multiply the distance aR of the radiant by the focal

cal

cal distance aF , and divide the product by their difference of distance; and the quotient will be the distance bI of the image of the radiant from the glass. Thus suppose the focal distance aF to be two inches, and the distance of the radiant R six inches; these being multiplied together make 12. But the difference between two inches and six inches is four; by which, divide the product 12, and the quotient is 3 inches for the distance of the image I of the radiant point R from the glass.

If three radiant points (fig. 9.) as D, E, F , (or any other number) be placed at any distance, as AD, AE, AF from the glass AB , greater than its focal distance; all the rays which flow from these points through the glass will form the images of these points in an inverted order, as d, e, f , behind the glass. Thus, the rays
 $DA,$

DA, DC, DB from the radiant D are converged in the directions Ad , Cd , Bd ; and from the image of the point D at d . The rays EA, EC, EB from the radiant E pass through the glass and go on in the directions Ae , Ce , Be , and by meeting at e they form the image of the radiant E. And the rays FA, FC, FB from the radiant F, after passing through the glass, go on in the directions Af , Cf , Bf , meet in the point f , where they form the image of the radiant F.

If more radiant points are placed between D and E, and between E and F, their rays will meet behind the glass, and form their respective images between d and e , and between e and f .

Hence we may easily apprehend how the images of objects are formed by the rays which flow from the object through a convex glass, and fall on a
piece

piece of white paper held upright at a proper distance behind the glass. For, let ACB (fig. 10.) be a convex glass, and DEF an object farther from the glass than its focal distance. The rays which flow from the extremities D and F , and middle point E of the object, and pass through the glass, will be collected into points at d , f , and e behind the glass, where they will form the images of the extreme and middle points of the object. But, as every intermediate point of the object between D and E , and between E and F , send out rays in the same manner, these rays which pass through the glass will be collected into all the intermediate points between d and e , and between e and f ; and consequently, a perfect image def will be formed of the object DEF ; but in an inverted form: and the image will be

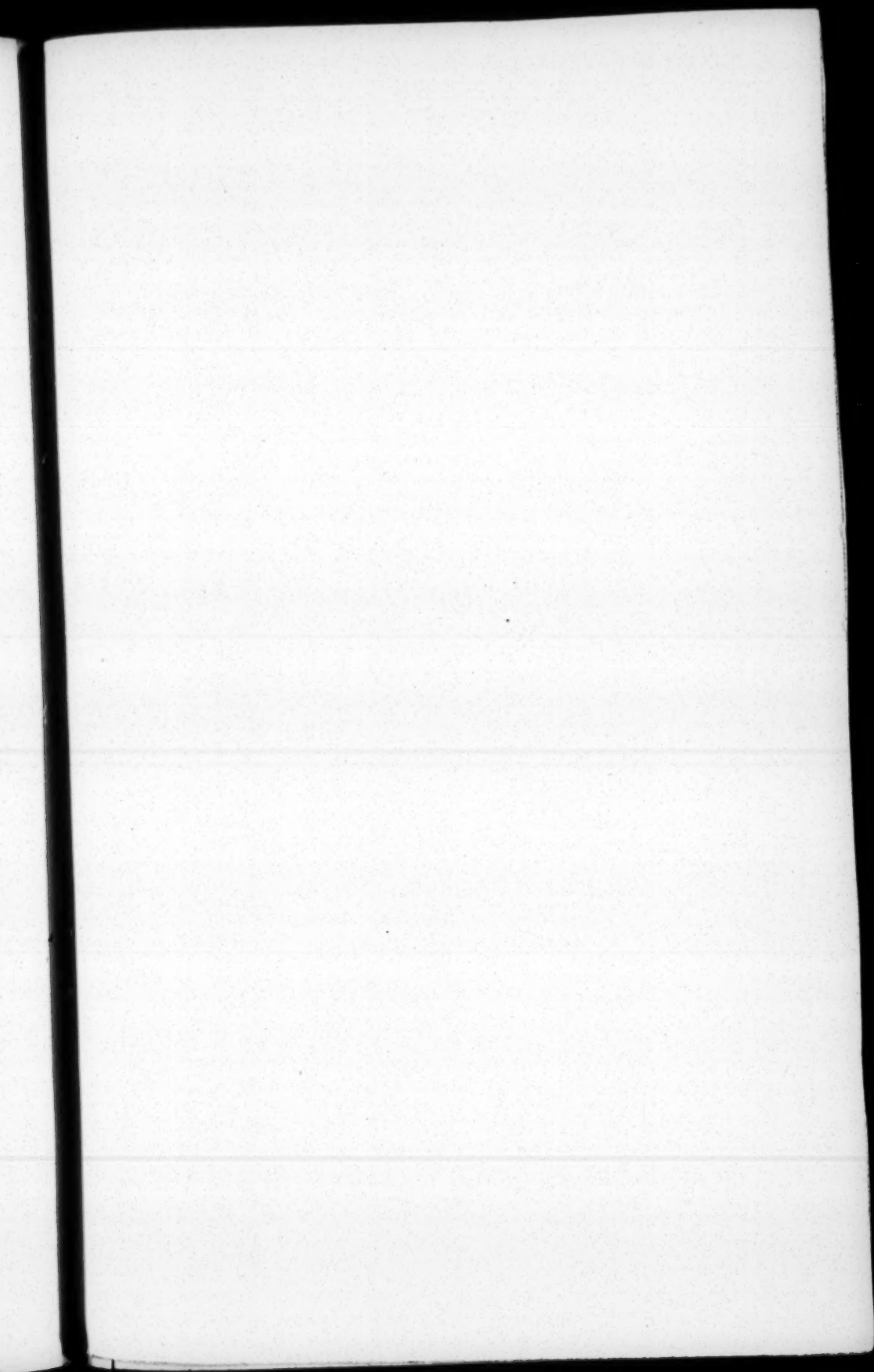


Fig. 10.

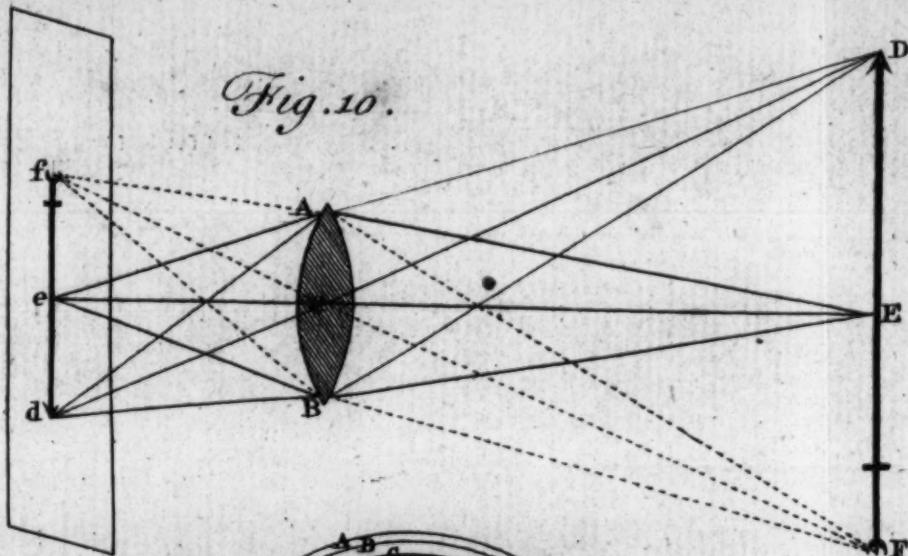


Fig. 14.

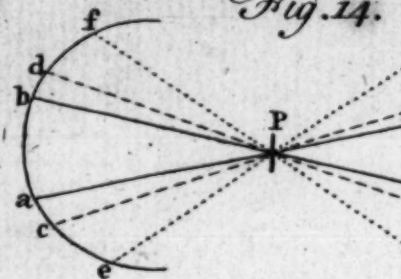


Fig. 11.

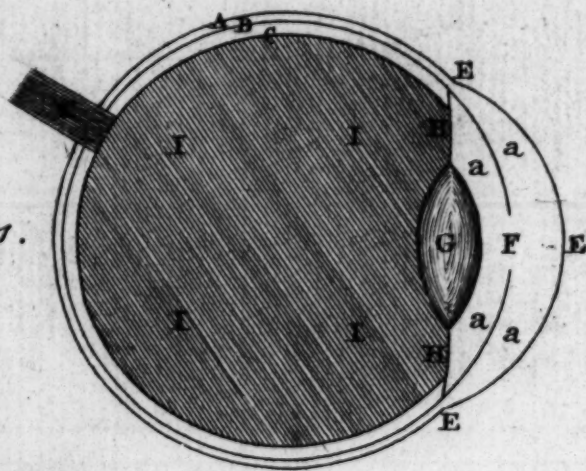


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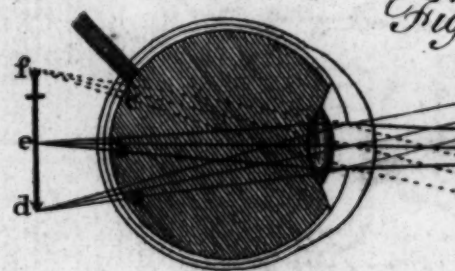
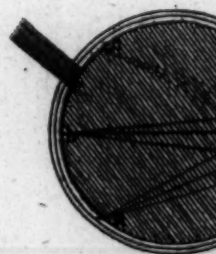
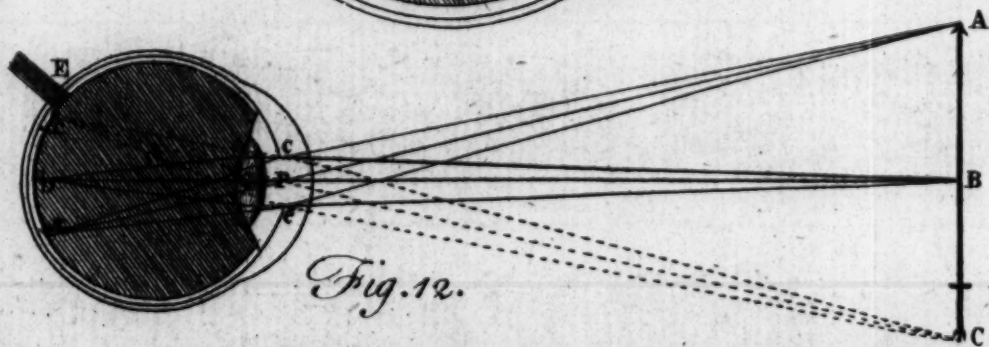
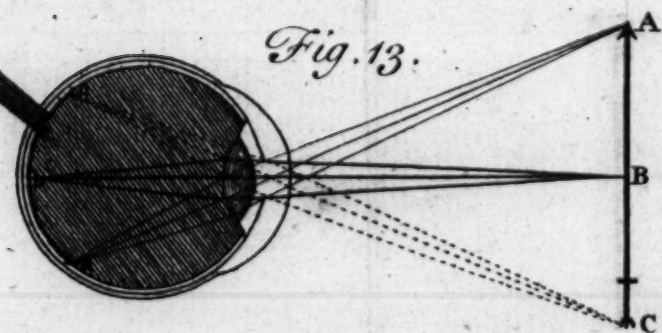
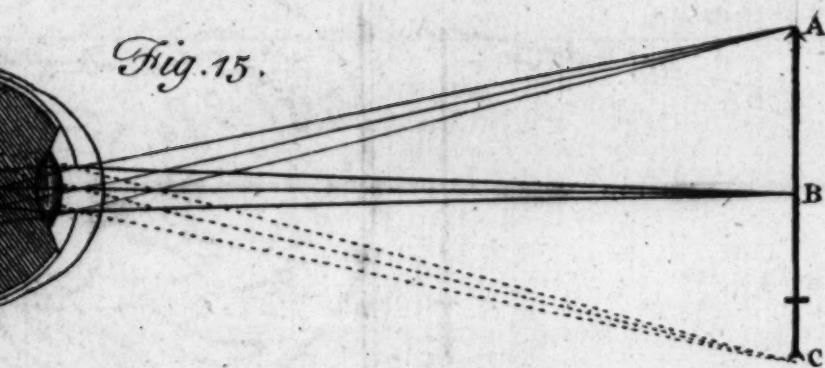
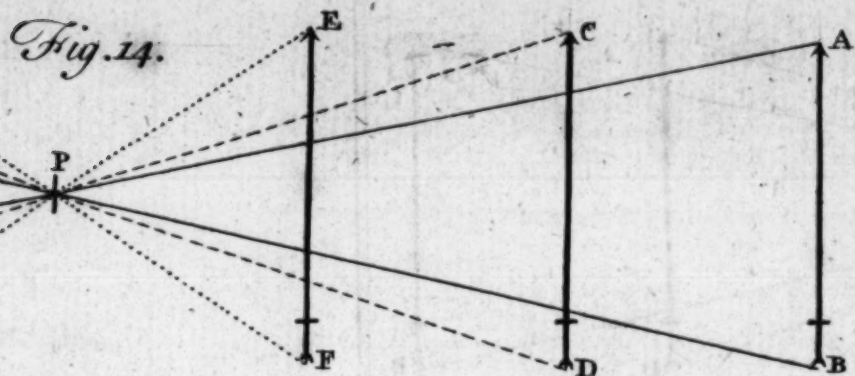
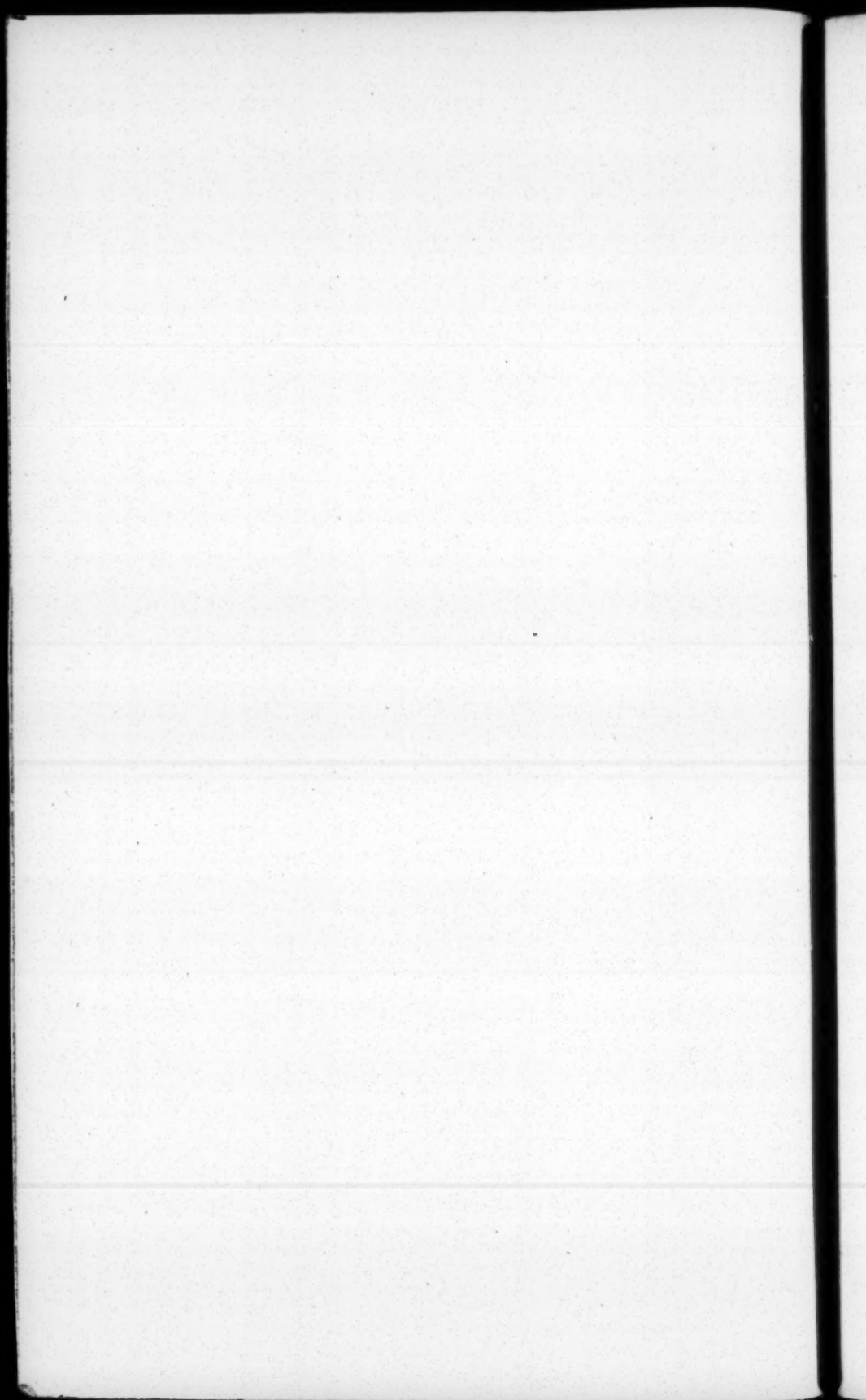


Fig. 12.







as much less than the object, as the distance of the object from the glass is greater than the distance of the image from the glass.

OF THE EYE, AND MANNER OF VISION.

Fig. 11. represents a section of the eye, very much magnified, and cut quite through the middle from the visible or fore part, to the back part which is concealed from sight in the head. The eye consists of three coats and three humours. The outer coat A is called the sclerotica, the middle coat B the choroides, and the innermost coat C the retina, which is only a continuation of the fibres of the optic nerve K, spread over the choroides like a fine net-work ; and on this, the images of all visible objects are formed.

The

The fore-part *EEE* of the sclerotica is transparent like fine thin clear horn, and is therefore called the cornea. The choroides *B* has a round hole in the fore part of it at *F*, and this hole is called the pupil, or sight of the eye. Behind the pupil lies the crystalline humour *G*, which is perfectly transparent, and of the form of a double-convex glass or lens. From the edge of the crystalline humour, all around, there proceeds a membrane *HH*, called the ciliary ligament, whose outermost edge adheres to the choroides *B*, and keeps the crystalline humour *G* in its proper place. Under the cornea *EEE* is a fine transparent fluid *aaaa*, called the aqueous humour, which also fills the pupil *F*, and the space between the choroides *B* and the crystalline humour *G* and ciliary ligament *HH*; at the back of which is the vitrious

vitrious humour IIII, which is transparent, but of a consistence as thick as jelly, and somewhat of a greenish colour like glass.

When an object, as ABC (fig. 12.) is before the eye, some of the rays which flow from every point of the object on the side next the eye (as Ac, AP, Ae, &c.) will pass through the pupil P, and chrystalline humour G, by which they will be collected into as many points, *a*, *b*, *c*, and every where between, from *a* to *b*, and from *b* to *c*; and will form an inverted image *abc* of the object upon the retina or bottom of the eye: for the chrystalline humour G acts like a lens, or double-convex glass (as in fig. 10.) and by this means the object ABC comes to be perceived; and the judgment tracing the rays back toward the object, in the direction they came from

from it, the object appears not inverted, but direct.

If the object ABC (fig. 13.) be brought nearer the eye, or the eye approaches nearer the object, the object will appear so much the bigger. For, the object ABC in fig. 12. is just equal to the object ABC in fig. 13. But the latter being twice as near the eye as the former, its image *abc* is twice as big on the retina.

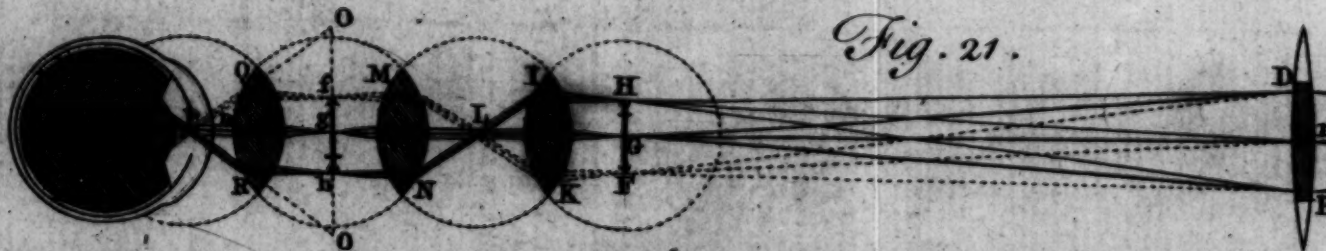
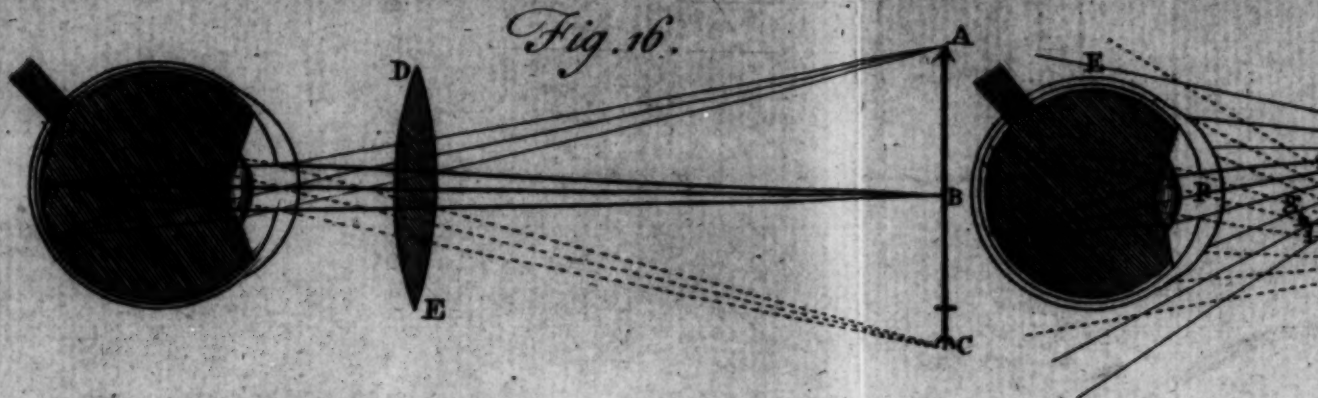
Let P (fig. 14.) be the pupil of the eye, and *fdbace* the retina. Now, it is evident by the figure, that the image of the object AB is limited to the space *ba* on the retina: but if AB be brought nearer to the eye, as suppose to CD, its image on the retina will fill the larger space *dbac*: and if it be brought still nearer, as to EF, its image will take up the yet larger space *fdbace*. So that, the greater the
angle

angle be under which the object is seen, the larger the object will appear to the eye.

In order that vision may be quite perfect or distinct, it is necessary that the rays which flow from every particular point of the object should be collected upon each particular part of the retina in so many points of the image; otherwise the image will appear confused or indistinct. Thus (fig. 12.) the rays Ac , AP , Ae which flow from the upper extremity of the object ABC through the pupil P , must be collected in a point a on the retina to form the image of the extremity A of the object: and so of all the rays which flow from every other point of the object. When the object is nearer the eye, as in fig. 13. the ciliary ligament contracts, and brings the chry-stalline humour forward in the eye,
and

and farther from the retina; otherwise we could see objects distinctly at only one distance. But the author of nature has so ordered it, that by means of this ligament, the chrystalline humour shall be so adjusted (in young eyes where the fibres are not rigid) as to advance backward or forward as the objects are farther or nearer, and so bring their rays to points on the retina.

When people grow old, the aqueous and chrystalline humours of their eyes grow too flat (fig. 15.) and therefore the rays flowing from an object, as ABC, are not converged into points on the retina *abc*, but form broad surfaces thereon; which renders vision imperfect and confused: for, if the rays could penetrate the retina and other coats of the eye, they would
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Fig. 17.

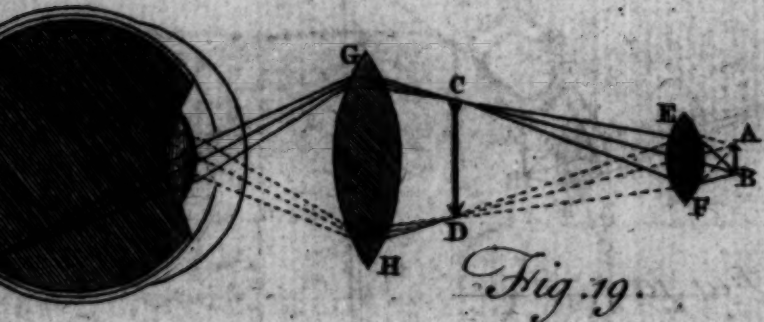
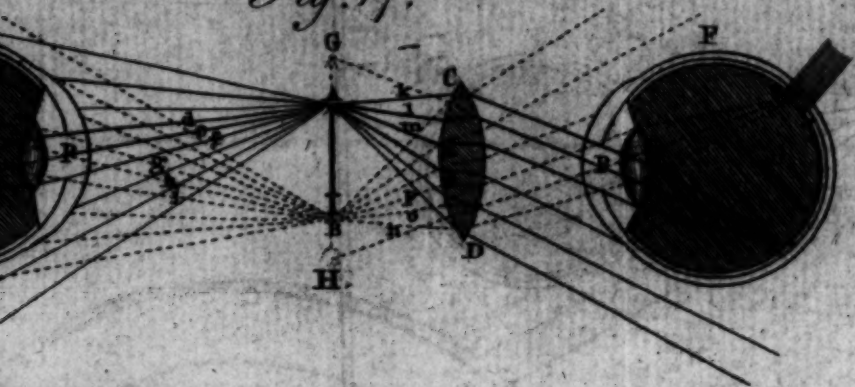
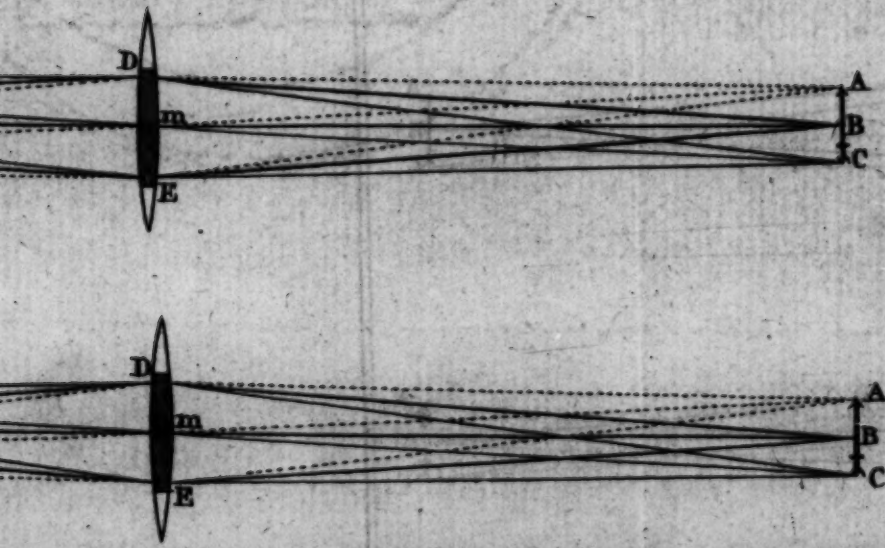
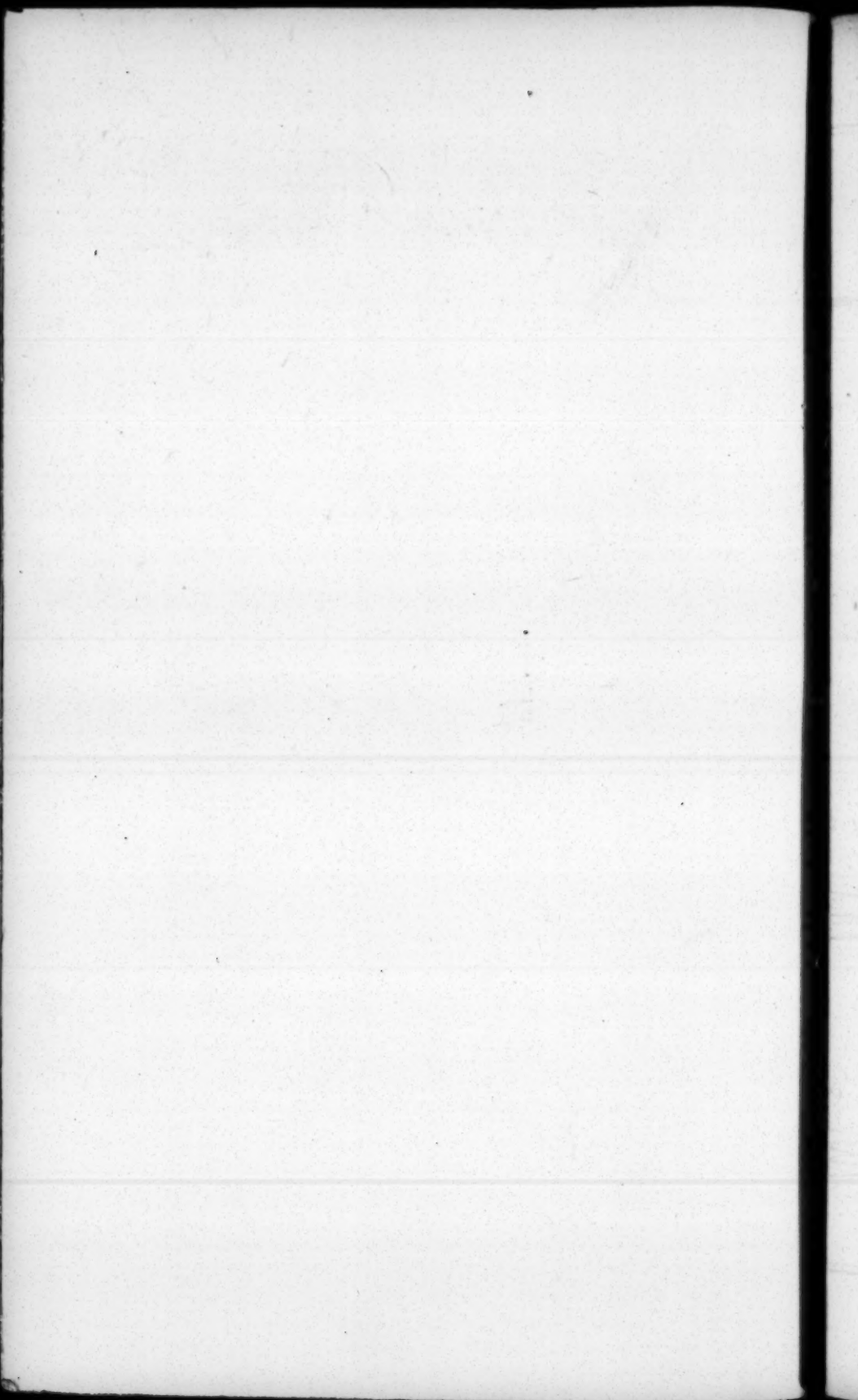


Fig. 19.



J. H. de la Roche.



form the true image of the object behind the eye ; as at *def*.

This defect of the eye is helped by convex glasses or spectacles, which cause the rays, after passing through them, to come less diverging to the eye, or parallel, or a little converging if the case requires it : and so, being helped a little towards a converging state before they enter the eye, by means of a convex glass at DE (fig. 16.) the humours of the eye converge them sufficiently afterward, so as to cause them to unite in points on the retina ; and therein to form the perfect image *abc* of the object ABC.

Although every point of an object AB (fig. 17.) reflects the rays of light in all manner of rectilineal directions, yet only those which come in the space *def* from the point A can enter the

the pupil *P* of the eye, and be converged to a point for forming the extremity *a* of the image *AB*. The like may be said of the rays which flow from the point *B* by reflection; for only those which come in the space *ghi* can enter the pupil *P*, and be converged to a point at *b*, for forming the image of the point *B* of the object *AB*. And the like is true with respect to the rays which flow from every intermediate point of the object *AB*: but these are left out, to avoid confusion in the figure.

If a double convex glass as *CD* be placed between the eye *F* and the object *AB*, the object will appear to be magnified. Thus, all the rays that flow from the top *A* of the object *AB*, in the space *klm*, and through the glass between *C* and *d*, will enter the pupil *P* of the eye, and be converged

verged into a point a on the retina, where they will form the image of the top of the object at A. And all the rays which flow from the lower point B of the object AB, in the space nop , and pass through the glass between D and e , will enter the pupil P and be converged in the point b where they form the image of the lower extremity B of the object. And as the object is seen through the glass under the angle GPH, equal to the opposite angle bPa , the object AB will appear so magnified as to fill up the whole space GABH. The distances of the eyes E and F from the object are equal; but by means of the glass, the image ab on the retina of the eye F, is double the size of the image ab on the retina of the eye E; and therefore, the object AB will appear to be twice

G

as

as long and twice as broad to the eye *E* as it does to the eye *E*.

The simple microscope is only a small double convex glass or lens, as *CD* (fig. 18.) beyond which, at a little less space than the focal distance of the glass, is placed a small object, as *ab*, from which the rays, flowing through the glass, and through the humours of the eye, are converged into points on the retina, where they form the image *AB*, greatly magnified, of the minute object *ab*. Since the rays diverge from every point of every visible object, and fall upon the eye in a diverging state, which (especially in young eyes) is necessary for distinct vision, the object is always placed a little within the focal distance of this microscope glass, which occasions the rays that flow through the glass, from each point of the object, to
diverge

diverge a little between the glass and the eye. If the rays come parallel from the glass to a common sound eye, they would converge to points before they reached the retina, and would render the image indistinct thereon; much more so if they came from the glass to the eye in a converging state.

In the compound microscope, (fig. 19.) the small object AB is placed a little farther from the convex lens than its focal distance, in order that the rays flowing from each particular point of the object may converge into each particular point between C and D, in which space they will form the image CD of the object. And if the focal distance of the other convex lens GH from the image, or rather a little within that distance, is the lens GH placed. Then, as the

rays flow from each point of this image, through the glass GH, they will pass on to the eye in a state of small divergency; and entering the eye in that state, they will be converged into points on the retina, by passing through the humours of the eye; and so they will form the image *de* of the image GH of the object AB.

Sound and perfect eyes perceive objects best, without glasses, at ten or twelve inches distance. But small microscope objects are too minute to be seen by the bare eye at such a distance. The magnifying power of the single microscope is as great as the focal distance of the glass CD (fig. 18.) is less than ten or twelve inches. The magnifying power of the compound microscope (fig 19.) is compounded of the proportion which the distance of the image from the object glass EF bears

to

to its distance from the eye glass GH, and of that which the distance of the object from the eye bears to its distance from the object glass.

The astronomical telescope consists of an object glass DE (fig. 20.) and an eye glass IK, placed at such a distance from each other, that their focuses, or centers of double convexities, may meet in a point as at G: and the pupil P of the eye is placed in the other focus of the eye glass. ABC is an object, supposed to be placed at a great distance from the telescope. The rays which flow from each point of the object ABC through the object glass DE, are by means of that glass converged and cross each other in all the points between H and F, in which space an inverted image FGH of the object ABC is formed in the focus of the object glass DE; and these rays

going on through the eye glass IK, will become parallel to one another between the eye glass and the eye. That is, the rays from the point H will be parallel between I and P, the rays from the point G will be parallel between n and P, and the rays from the point F will be parallel between K and P; because they flow from the image in the focus of the glass IK; and crossing in the pupil P, they will be converged into all the points on the retina between L and N, where they will form the image of the object ABC. And this image being seen by the eye under the angle IPK, it will appear to be so much magnified, as to fill the whole space OHGFO.

To find the magnifying power of this telescope, divide the focal length Gm of the object glass by the focal length Gn of the eye glass, and the quotient

quotient will express the magnifying power. But this telescope shews the object in an inverted position, because it has only one eye glass.

The common telescope (fig. 21.) which shews objects (as ABC) in their true position, consists of an object glass DE, and three eye glasses IK, MN, and QR, so placed, that the focusses of DE and IK may meet in G; those of IK and MN may meet in L; and those of MN and QR may meet in g. Then, the image of the object will be formed in an inverted position between H and F in the focus of DE; then the rays flowing through IK will become parallel which belong to each point of the image, and crossing at L, and going on, will pass through the glass MN, which will converge them into points in its focus, and will there form the second image

fgb erect; which image will be viewed by the eye in the focus *P* of the eye glass *QR*. And as this last image will be seen under the angle *QPR*, it will appear so magnified, as to fill the whole space *OfgbO*.

All the three eye glasses, *QR*, *MN*, and *IK*, are of equal focal distances; and to find the magnifying power of this telescope, divide the focal length *Gm* of the object glass *DE* by the focal length *gn* of the eye glass *QR*, and the quotient will express the magnifying power of the telescope.

T H E

PART THE FOURTH

OF

ASTRONOMY.

the sun is the center of the system, and all the planets move round him, at different times, and at different distances from him. One moon moves round the earth, and two round Jupiter, and two round Saturn.

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The planets are moved by a powerful force impressed upon them by the deity at the beginning, which force would for ever have caused them to move in straight lines: but the sun being endowed with an attractive power

OF THE SOLAR SYSTEM.

THE solar system consists of the sun, six primary planets, ten moons, and several comets, of which the number is not yet certainly known.

The sun is placed in the center of the system, and all the planets move round him, in different times, and at different distances from him. One moon moves round the earth, four moons round Jupiter, and five round Saturn.

The planets are moved by a projectile force impressed upon them by the deity at the beginning, which force would for ever have caused them to move in straight lines: but the sun being endued with an attractive power

power (no ways inherent in matter, or peculiar to it) this power draws the planets toward the sun just as much as the projectile force would carry them off from the sun ; and so compels them to revolve about the sun, in the same orbits, over and over again, as they did at the beginning. Their periods round the sun compleat their years, and their rotations on their axes compleat their days and nights.

The times in which the planets make their annual periods round the sun are found by observation ; and their comparative distances from the sun have been also ascertained by observation. And it is found, that the squares of the periodical times bear the same proportion to one another as the cubes of their distances from the sun do bear to each other. And hence it comes out, that the sun's attractive power, which

which retains all the planets in their orbits, decreases as the square of their distances increase from the sun.

The times in which the planets perform their revolutions about the sun, and their relative or comparative distances from the sun, are as follows, supposing the earth's mean distance from the sun to be divided into 10000 equal parts.

	<i>Periodical Times.</i>			<i>Comp. dist. as in the scale</i>
	<i>days.</i>	<i>hours.</i>	<i>parts.</i>	
Mercury	87	23	3871	of equal parts, in fig. I. where each division is supposed to be sub-divided into one hundred.
Venus	224	17	7233	
The earth	365	6	10000	
Mars	686	23	15237	
Jupiter	4332	12	52009	
Saturn	10759	7	95400	

Having found the comparative distance of the planets from the sun, in such parts as the earth's distance from the

the

the sun contains 10000, if we can find the real distance of either of the planets from the sun in miles, we may find thereby the real distances of all the rest.

By observations of the late transit of of Venus (A. D. 1761. June 6.) the earth's distance from the sun is found to be 95,173,000 English miles. Therefore,

As 10,000 is to 95,173,000, so is 387, Mercury's distance from the sun in parts, to 36,841,468 his distance from the sun in miles. And,

As 10,000 is to 95,173,000, so is 7233, Venus's distance from the sun in parts, to 68,891,486, her distance from the sun in miles. Again,

As 10,000 is to 95,173,000, so is 15237, Mars's distance from the sun in parts, to 145,014,148, his distance from the sun in miles. Likewise,

As

As 10,000 is to 95,173,000, so is 52009, Jupiter's distance from the sun in parts, to 494,990,976, his distance from the sun in miles. Once more,

As 10,000 is to 95,173,000, so is 95400, Saturn's distance from the sun in parts, to 907,956,130, his distance from the sun in miles.

As 7 is to 22, so is the diameter of a circle to its circumference. Hence, from the above distances of the planets from the sun, the circumference of their orbits are as follows.

Mercury's, 231,574,940 English miles; Venus's 433,032,198 miles; the earth's 598,230,286; Mars's 911,517,502; Jupiter's 3,111,371,849 miles; and Saturn's 5,707,152,817.

Dividing the circumference of each planet's orbit by the number of hours contained in the planet's periodical revolution round its orbit, we have the
number

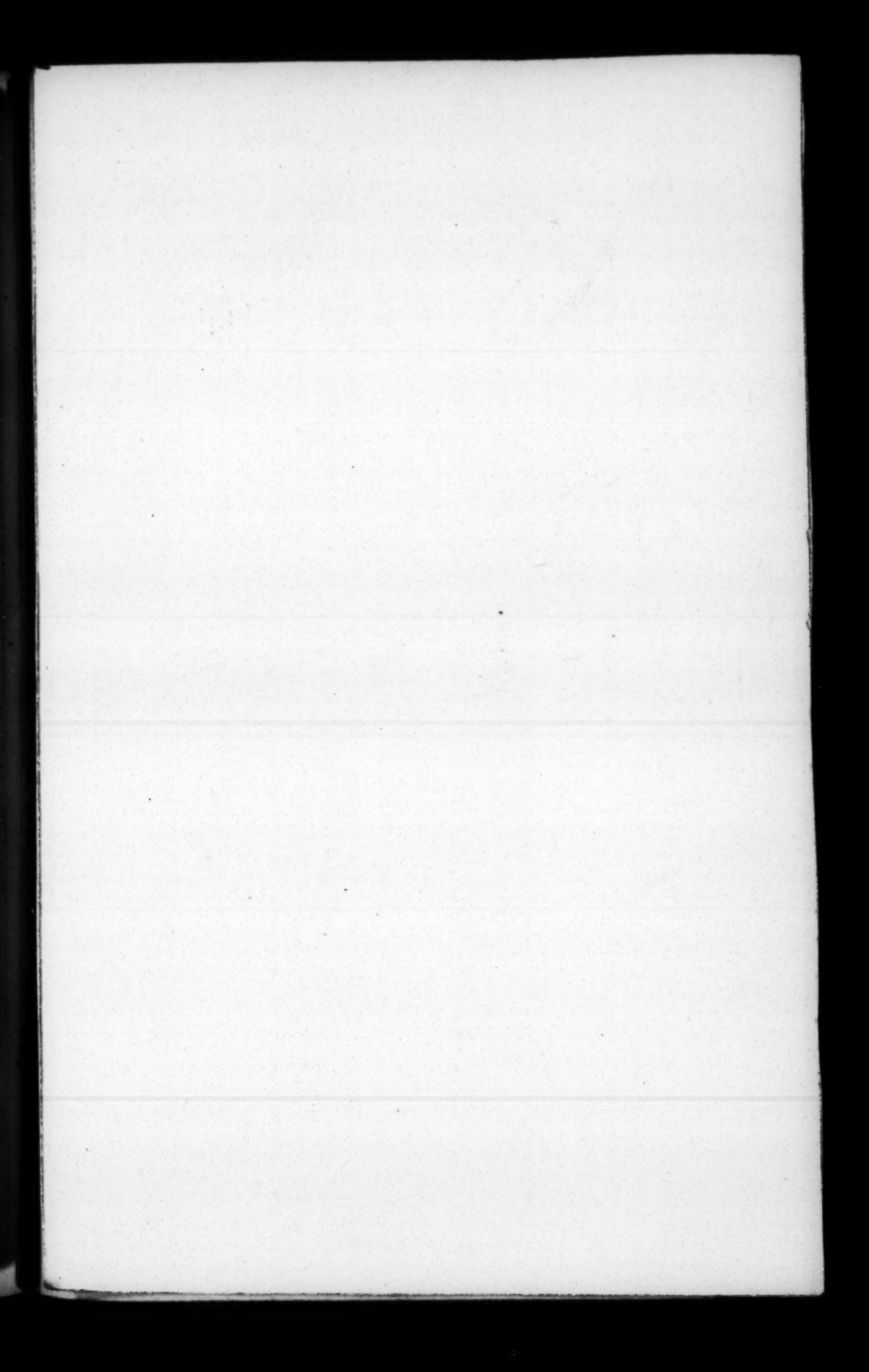
number of miles which each planet moves in an hour. And they are as follows.

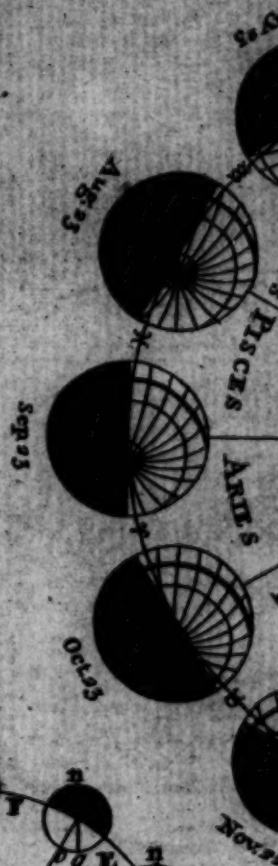
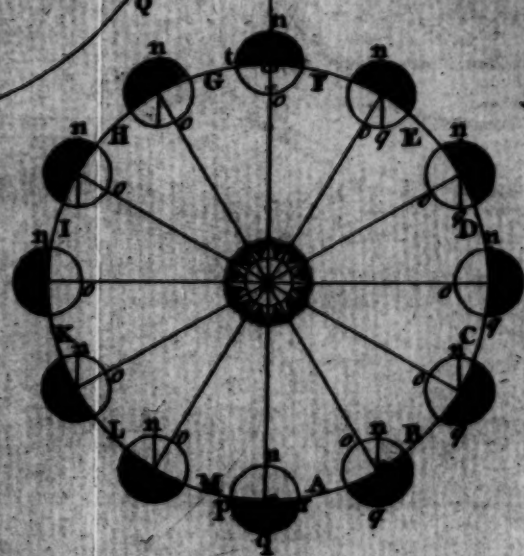
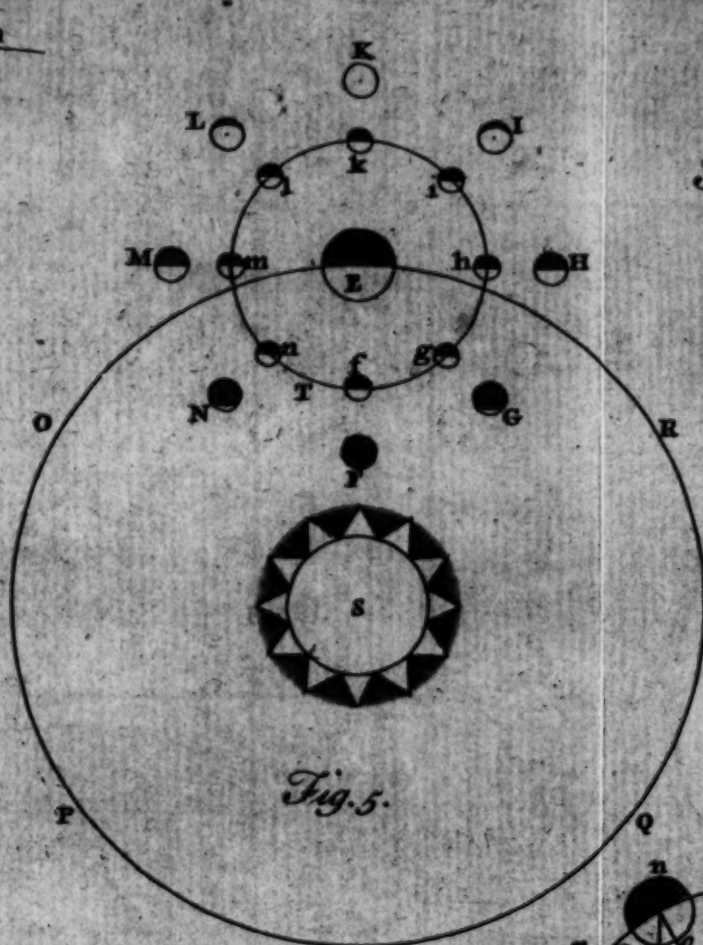
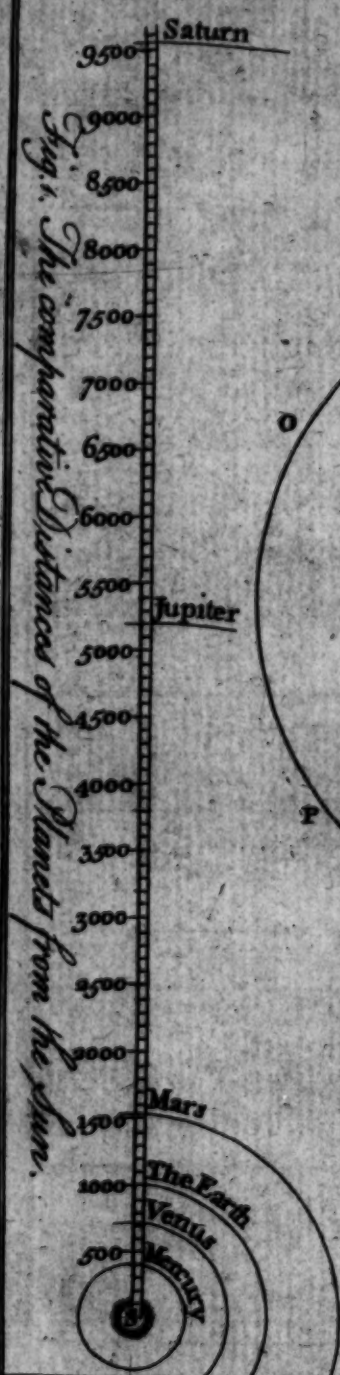
Mercury, $109,699\frac{1}{1000}$ miles ; Venus $80,295\frac{2}{1000}$; the Earth $68,243\frac{2}{1000}$; Mars $55,287$; Jupiter $29,083\frac{6}{1000}$; and Saturn $22,101\frac{6}{1000}$ miles.

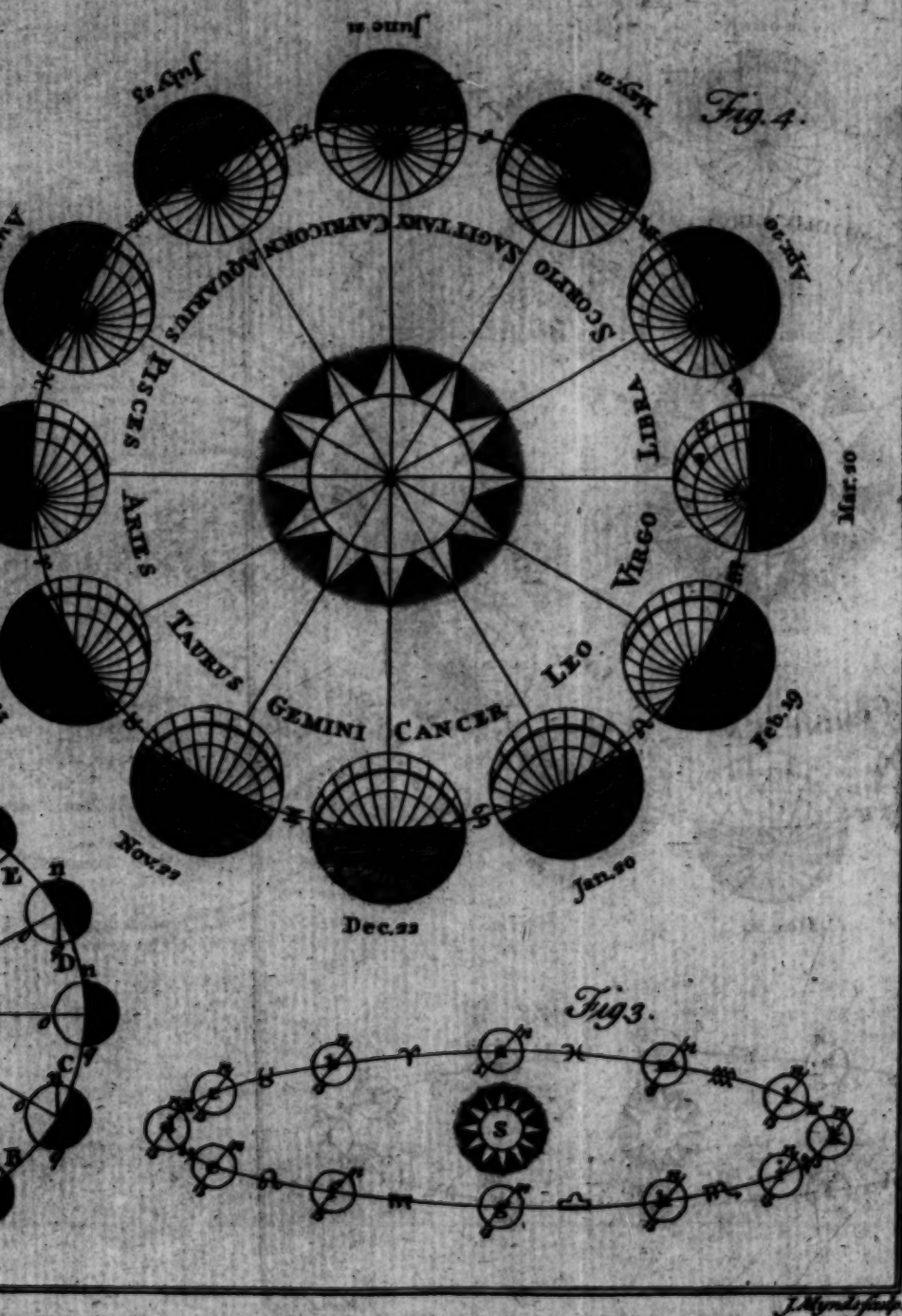
Venus turns round her axis in 24 days 8 hours, the earth turns round its axis in 24 hours, Mars in 24 hours 40 minutes, and Jupiter in 9 hours 56 minutes. The times in which Mercury and Saturn turn round their axes are unknown to us.

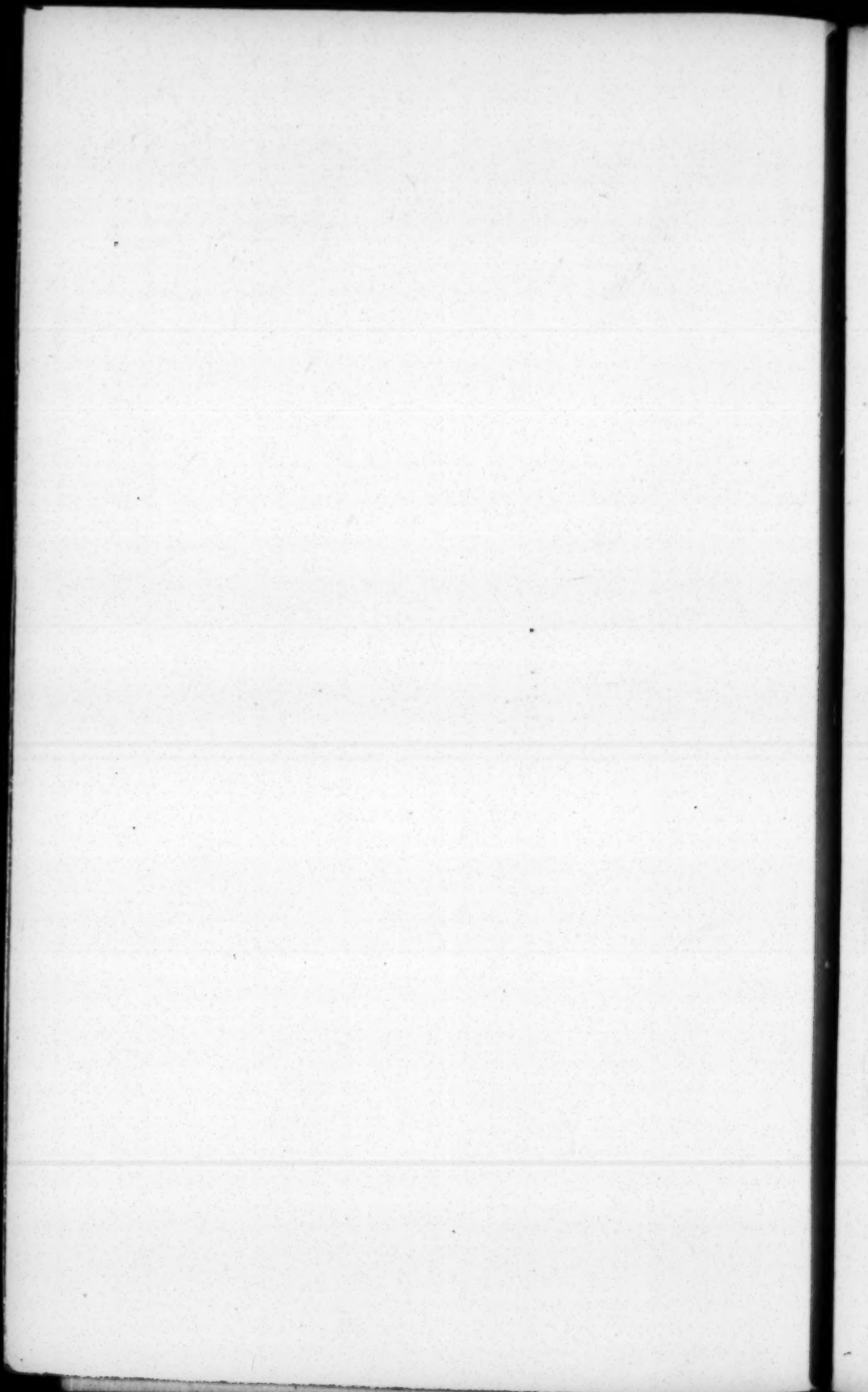
To bring all these things together in view, the following table is constructed.

A TABLE









A TABLE shewing the times in which the planets describe their annual periods round the sun, and their diurnal rotations on their own axes; their distances from the sun, their circumferences of their orbits, and the number of miles they advance every hour therein.

Names of the Planets.	Their Annual Periods.	Their Diurnal Rotations	Comparative Dist. fr. the Sun in Parts.	Real Distances from the Sun in English Miles.	Circumference of their Orbits in English Miles.	Hourly Motions in their Orbits.
Mercury.	87 23	Unknown Days. 8 Hou. Min.	3871	36,841,468	231,574,940	109,699 $\frac{16}{100}$
Venus.	224 17	24 Hou. 8 Min.	7233	68,891,486	433,032,198	80,295 $\frac{24}{100}$
Earth.	365 6	24 Hou. 0 Min.	10000	95,173,000	598,230,286	68,243 $\frac{24}{100}$
Mars.	686 23	24 Hou. 40 Min.	15237	145,014,148	911,517,502	55,287 $\frac{0}{100}$
Jupiter.	4332 12	9 Hou. 56 Min.	52009	494,990,976	3,111,371,849	29,083 $\frac{68}{100}$
Saturn.	10759 7	Unknown	95400	907,956,130	5,707,152,817	22,101 $\frac{64}{100}$

The moon is the earth's satellite ; her distance from the earth is 240,000 miles ; and she goes round her orbit from change to change in 29 days 12 hours 44 minutes 3 seconds. Jupiter has four moons, and Saturn five.

As the square of the earth's period round the sun (*viz.* 365 days 6 hours) is to the cube of its distance from the sun, so is the square of any other planet's period round the sun to the cube of its distance from him.

The sun's parallex, as deduced from the transit of Venus, is $8\frac{6}{100}$ seconds of a minute of a degree, which shews by calculations of a plain right angled triangle, that the sun's mean distance from the earth is 95,173,000 English miles.

For, the logarithmic sine (or tangent) of $8\frac{6}{100}$ seconds is 5,6219140 ; which being subtracted from the
radius

radius 10,000,000, leaves remaining the logarithm 4,3780860, whose number is 2388284; which is the number of semidiameters of the earth that the sun is distant from it. And this last number, 2388284 being multiplied by 3985, the number of English miles contained in the earth's semidiameter, gives 95,173,117 miles for the earth's mean distance from the sun. But, because it is impossible, from the nicest observations of the sun's parallex, to be sure of his true distance from the earth within 100 miles, we do at present, for the sake of round numbers, state the earth's mean distance from the sun at 95,173,000 English miles.

In so small an arc as $8\frac{6}{10}^{\circ}$ seconds of a degree, the sine and tangent are so nearly equal, that we may without any sensible error consider them as equal.

equal. And there is no difference between them in the logarithmic tables.

OF SIDEREAL AND SOLAR TIME.

In fig. 2, let S be the sun, $npqr$ the earth, turning round its axis according to the order of the letters, from west, by south to east; let n be any given place on the earth's surface, whose meridian is naq , and let N be a fixt star, at such an immense distance, that the whole orbit of the earth $ABCDEFGHIKLMA$ is but a point in comparison to that distance. Then let the earth be in any part whatever of its orbit, as at b, c, d, e, f , &c. when the said meridian is in the position bn, cn, dn, en, fn , &c. its plane will

will pass through the star; that is, whenever the meridian becomes parallel to its position *an*, the star will be upon that meridian, let the earth be in any part of its orbit whatever.

When the meridian, on any day, becomes parallel to the situation that it had at any given instant on the day before, the earth has made a compleat revolution about its axis; and this it always does, when any given meridian has revolved from any star to the same star again; and the time of such a revolution is in 24 sidereal hours, which is called a sidereal day.

If the earth were always to remain at *a*, the meridian *an* would always revolve from the sun to the sun again in the same time that it does from the star *N* to the same star again; and then 24 sidereal hours would be the same as 24 solar hours: for the plane
of

of the meridian *an* continued, would pass through the sun's center *S*, at the same instant of its passing through the star *N*.

But as the earth has a progressive motion in its orbit through *ABCD*, so as to go round its orbit in a year, according to the order of the letters, the said meridian will revolve sooner and sooner every day to the star than to the sun; and so much sooner every day, that in 365 days, as measured by the sun, the meridian will have revolved 366 times to the star. So that, whatever the number of solar days in the year be, the number of siderial days will exceed it by one.

Thus, when the earth is at *a*, the point *n* has both the sun and the star on its meridian; but in a month afterward, when the earth has advanced to *b*, the meridian will have made a certain

tain number of revolutions to the star, as often as it has been in the position of bn , parallel to an ; but then when it is at bn , the point n (or place on the meridian) must revolve from n to o before it has the sun on its meridian; and the arc no is a twelfth part of the earth's circumference, which is equal to two hours revolution. And therefore, the number of solar days in a month is (among them all) two hours longer than the number of siderial days in that time.

When the earth is at C , the point n will be directed to the star four hours sooner than it can revolve through the arc no to the sun. At d six hours sooner; at e eight hours; at f ten hours; and at g the point n will have the star N on its meridian at midnight; or 12 hours before it revolves half round, through the arc n to the the sun S .

At

At *b* the accomplishment of the sidereal day will be 14 hours sooner than the solar, at *i* 16, at *k* 18, at *l* 20, at *m* 22, and at *a* 24; for at *a*, one turn of the earth on its axis will be lost with regard to the number of days and nights in the year, on account of the earth's motion round the sun.

OF THE DIFFERENT SEASONS.

In fig. 3 let *S* be the sun, $\gamma \delta \Pi \alpha \beta \eta$, &c. the earth's annual orbit represented in a very oblique view; *a, b, c, d, e, f,* &c. the earth in twelve different parts of its orbit; and *ns* the earth's axis, of which *n* is the north pole and *s* the south pole. In the earth's whole annual course round the sun, its axis *ns* is $23\frac{1}{2}$ degrees inclined from a perpendicular to its orbit; and

and its axis still keeps the same oblique direction. Therefore, it is plain, that whilst the earth moves through the signs $\gamma \delta \Pi \Xi \Omega$ and μ , the north pole of its axis constantly inclines more or less toward the sun, and most of all when the earth is at d ; as the earth moves through $\triangle m \uparrow \downarrow \text{and } \times$ its north pole n inclines more or less from the sun; and most of all from him when the earth is at k . This obliquity is the cause of all the vicissitudes of the seasons.

In fig. 4, the observer is supposed to be placed at a great distance above the center of the earth's orbit $\gamma \delta \Pi \Xi \Omega \mu \triangle m \uparrow \downarrow \text{and } \times$, where he sees the northern half of the earth, of which N is the north pole (see the earth at March 20) where all the meridians meet. P is the north polar circle, T the tropic of cancer, and E the equator.

H

tor. The side of the earth that is at any time turned toward the sun S has day, whilst the side that is the turned from him has night.

On the 20th of March, when the earth enters the beginning of ♎ Libra, and the sun as seen from the earth, appears to be at the beginning of the sign ♈ Aries, the boundary of light and darkness cuts the earth in its north pole; and then all the places on the earth go equally through the light and the dark, which makes day and night then equal. In April the north pole is considerably in the light, and the day is longer than the night; in May more so, and on the 21st of June most of all; the whole north polar circle being then in the light, and the days at the longest in the northern half of the earth. From that time the days shorten and nights lengthen, till September 23, when

when they are again equal as on the 20th of March. From September 23 to March 20, the north pole is continually in the dark, but most so on the 22d of December, when the whole polar circle is in the dark, and the days at the shortest and nights at the longest, all the way between the equator and polar circle. At each pole there is but one day and one night in the whole year.

This figure shews the position of the earth at the time of its entrance into each sign of the ecliptic, and how it is then enlightened by the sun. Its motion round its axis being the cause of days and nights, and its motion round the sun on its oblique axis the cause of the different lengths of days and nights, and of all the variety of the seasons.

H 2

When

When the earth enters any sign of the ecliptic, the sun then seen from the earth appears to enter the opposite sign.

OF THE MOTIONS AND PHASES OF THE MOON.

Which ever side of the moon is toward the sun S at any time, will then be enlightened by the sun ; and the other half will be in the dark. And as the moon goes round the earth, she will appear to be more or less enlightened, as the enlightened side of her is more or less turned toward the earth. See fig. 5.

Let OPQR be the annual orbit of the earth E, and T the orbit of the moon, in which she goes round the earth from change to change, in 29 days,

days, 12 hours, 44 minutes, 3 seconds, according to the order of the letters *fghiklmn*. When the moon is at *f*, her dark side is toward the earth, and she becomes invisible, because she can then reflect none of the sun's light to the earth; and has no light of her own to shine by. When she is at *g*, a little of her enlightened side will be toward the earth; and she will appear horned as at G. When she is at *h*, half her enlightened side will be toward the earth; and she will appear half full, as at H, when we say she is in her first quarter, encreasing. When she is at *i*, she will appear gibbous, as at I, the greatest part of her enlightened side being then toward the earth. When she is at *k*, the whole of her enlightened side will be toward the earth; and she will appear quite full, as at K. When she is at *l*, her whole en-

H 3

lightened

lightened side cannot be seen from the earth; and she will appear gibbous, on the decrease, as at L. When she is at *m*, half her enlightened side will be toward the earth, and she appears half decreased, as at M; when we say she is in her third quarter. When she is at *n*, the greatest part of her enlightened side is turned from the earth, and she appears horned, not far from the change. And when she comes to *f*, she is all dark toward the earth, as at F; and then she is quite invisible; at which time we say it is new moon.

Both the earth and moon cast shadows directly outward from their dark sides. And hence, it is plain, that if the moon's orbit lay even (or in the same plane) with the earth's orbit, the moon's shadow would fall on the earth at every change, and the earth's shadow would fall on the moon

at

at every full. In the former case there would always be an eclipse of the sun, and in the latter case an eclipse of the moon. But one half of the moon's orbit is on the north side of the earth's orbit, and the other half on the south side thereof. So that the moon's orbit crosses the earth's orbit in two opposite points, which are called the moon's nodes. And there can be no eclipse of the sun but when the moon changes in or near either of the nodes; nor can the moon be eclipsed but when she is full, in or about either of her nodes.

The moon's orbit is elliptical, and the earth's center is in one of its foci.

OBSERVATIONS ON THE ASTRONOMICAL PART OF THIS WORK.

I. If the earth were fixed immovable in its orbit, so as to have no progressive motion therein, and to turn round its axis with the same velocity it does at present ; its axis being supposed to be perpendicular to the plane of its orbit : and the moon were to revolve in her orbit with her present velocity, her orbit being supposed to be circular, and she to be of the apparent bulk of the sun : In this case, the solar or natural day would be of the same length with the siderial day ; namely, 23 hours 56 minutes 4 seconds : the sun would always appear to revolve in the plane of the equator, and the days and nights would be always of an

an equal length. The moon would likewise revolve in the plane of the equator, from the sun to the sun again, or from change to change, in the time she now goes round her orbit; namely, in 27 days 7 hours 43 minutes. The diameters or breadths of the sun and moon would always appear to be equal. The moon would eclipse the sun totally, but without any continuance of total darkness, at the time of every new moon. These eclipses would be no where total but at the equator; and partial every where else, so far as they extended, which would be about 2400 miles on each side of the equator; beyond which, farther north or south, the sun would never be eclipsed at all. The moon would be eclipsed by the earth's shadow every time she was full; and the eclipse would be total, as seen from any part of the earth.

II. If

II. If the moon's orbit acquired an elliptical form, and all the other circumstances remained the same as above. The length of days and nights, and of the lunations would be as above mentioned. Whatever part of the moon's orbit was once between the earth and the sun would always be so. If it was the apogee point, the moon would be too far from the earth at the change to hide the whole body of the sun, even at the equator; at which all the sun's eclipses would be annular. If the perigee point of the moon's orbit was toward the earth, all the sun's eclipses would be total at the equator, and the darkness would continue about four minutes. If the middle point between the apogee and perigee were toward the sun, his eclipses would be total at the equator without

out any continuance of darkness. The lunar eclipses total, as above.

III. With these circumstances, suppose now that the earth should revolve about the sun, with its present annual velocity, but in the plane of the equinoctial. The days and nights would always be of equal length, only the 24 solar hours would be 3 minutes 56 seconds longer than if the earth had no annual motion: but there would be no difference of seasons. The lunations would be 29 days 12 hours 44 minutes 3 seconds in length. The eclipses of the sun would be sometimes total with continuance, at the equator, sometimes total without continuance, and at other times annular. Those of the moon would be as above mentioned.

IV. If now, the earth should go round the sun in the plane of the ecliptic, and the moon go round the earth

earth in the plane of the ecliptic; and the earth's axis should become inclined to the ecliptic as it is at present. This would bring on all the inequality of days and nights, and all the vicissitudes of seasons we now enjoy: but still the sun would be eclipsed at the time of every new moon, and the moon at the time of every full. But the central eclipses of the sun would not be confined to the equator; for, in our summer, the center of the moon's shadow would take the earth at the equator, where the general eclipse would begin: at the middle of the general eclipse the center of the shadow would fall on the northern tropic, and thence it would move obliquely southward, and would go off the earth at the equator. In spring, the center of the moon's shadow would go obliquely over the earth, from the southern

southern tropic to the northern : in autumn it would go obliquely over the earth from the northern tropic to the southern. And in winter it would first touch the earth at the equator, then bend southward to the southern tropic ; from thence toward the equator again, and would at last leave the earth at the equator. All the eclipses of the moon would be total and central (as above) let them be seen from any part of the earth whatever.

V. If the moon's orbit should become inclined to the ecliptic, as it now is, and all the other circumstances remain as above; the nodes of the moon's orbit having no motion, but always to keep in the same opposite points of the ecliptic ; there could never then be above six eclipses in the year ; and when there were that number, four of them would be of the sun and
two

two of them of the moon. At other times, as the moon might happen to change in or near the nodes, there would only be three eclipses ; of which there would be two of the sun and only one of the moon. And the time between these eclipses about the different nodes would be half a year. So that, in whatever seasons the eclipses once fell, they would always do so again. The moon's eclipses would sometimes be total and at other times partial.

VI. If the moon's nodes should afterwards acquire a retrograde motion, such as they now have, and every thing else continue as above : this would occasion all the variety of eclipses of the sun and moon that we now have : to explain which, would require the writing of a large volume.

TO

TO REPRESENT THE MOON'S ORBIT ON A CELESTIAL GLOBE.

Tie a silk thread round the ball of the globe on the ecliptic, and then find the place of the moon's ascending node in the ecliptic by an ephemeris.

This done mark the place of the ascending node in the ecliptic with a chalk, and also the opposite points of the ecliptic for the place of the descending node: mark also the two points of the ecliptic which are half way between the nodes, or 90 degrees from each.

Then, reckoning 90 degrees from the ascending node, according to the order of the signs, set the silk thread $5\frac{3}{4}$ degrees northward there, or half way between the nodes; and on the
opposite

opposite side of the globe set the thread $5\frac{3}{4}$ degrees south of the ecliptic: and lastly adjusting the thread by hand to be like a great circle on the globe crossing the ecliptic at an angle of $5\frac{3}{4}$ degrees in the nodes, the thread will truly represent the moon's orbit in the heavens for that time, and shew what stars it passes either through, or near to. And finding the moon's place by an ephemeris for the given time look for the same place in the ecliptic, and right against it; under the thread, will be the moon's place in her orbit for that time.

The diameter of the moon is to that of the earth as 100, to 365.—The moon's velocity is about 2200 miles an hour.

Note, In 24 hours the moon moves 13 degrees, 10 minutes of a degree and 35 seconds; and every minute of
a degree

a degree in the moon's orbit is equal to a whole degree on the earth's surface.

Therefore in 24 hours the moon moves 47435 miles.

FINIS.

ERRATA.

- Page v. (Preface) l. 6. *for*, 31, *r.* 32.
 xx. (Preface) l. 8, 9. A seventeenth boy of a large size must be used for the sun in the center. This should have been printed as a note.
 10. l. 11. *after*, table D, *add* (fig. 3.)
 11. l. 10. *for*, hanging *for*, *r.* hanging on.
 29. l. 16. *for*, BC, *r.* BA.
 36. l. 7. *for*, forty-four, *r.* forty-two.
 37. l. 5. *after*, AB, *add*, (fig. 25.)
 39. l. 14. *after*, hundred, *add*, thousand.
 45. l. 21. *for*, right line, *r.* right sine.
 46. l. 2. *for*, Dfg, *r.* dfg.
 77. l. 2. *for*, 47, *r.* 56.
 103. l. 7. *for*, debi, *r.* debf.
 138. l. 13. *for*, parallex, *r.* parallax.
 144. l. 10. *for*, $\Pi \Xi \Upsilon$, *r.* $\Pi \Xi \Omega \Upsilon$.

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